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NAVAL SHIPS' TECHNICAL MANUAL

CHAPTER 562

SURFACE SHIP STEERING SYSTEMS

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NOTE

THIS CHAPTER HAS BEEN REFORMATTED FROM DOUBLE COLUMN TO SINGLE COLUMN TO SUPPORT THE NSTM DATABASE. THE CONTENT OF THIS CHAPTER HAS NOT BEEN CHANGED.

CHAPTER 562

SURFACE SHIP STEERING SYSTEMS

SECTION 1.

GENERAL AND SAFETY PRECAUTIONS

562-1.1 GENERAL

562-1.1.1 INTRODUCTION. This NSTM chapter covers the steering machinery and controls used on most large Navy surface ships. The major aspects of steering equipment, operation, and maintenance are explored. The information presented is intended to supplement the procedures and requirements in the steering systems' technical manuals and Maintenance Requirements Cards (MRC). The chapter is divided into the following sections:

a. **General and Safety Precautions** outlines the scope of the chapter and the safety precautions that must be followed when working with steering systems.

b. **Functional Characteristics** provides information concerning how the steering system performs its primary function of maneuvering the ship.

c. **Steering System Configurations** presents an overview of the types of steering systems in use and identifies the interfaces with other shipboard systems.

d. **Hydraulic Equipment** describes the rudder actuators, hydraulic power units, and supporting equipment used on surface ship steering systems.

e. **Steering Controls** highlights the major components of hand (electric), hydraulic telemotor, and digital control systems.

f. **Rudder Position Feedback Equipment** describes the mechanical and electrical follow-up systems that join the steering machinery to the controls.

g. **Emergency Equipment** outlines the types of equipment available to control the rudder in the event of a failure in the main steering system.

h. **Description of System Operation** describes how the steering equipment operates as a system.

i. **Operating Procedures** presents an overview of recommended operating procedures and suggests measures to take in response to a failure within the system.

j. **Maintenance and Testing** describes preventive and corrective maintenance procedures that are applicable to most systems. Steps that should be taken to preserve the steering system when the ship is in an industrial activity environment, such as during an overhaul period, are also outlined.

Figure 562-1-1 is a map of this NSTM chapter. The map outlines the topics discussed in each section and guides the user to a specific topic of interest.

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562-1.2 BASIC TERMINOLOGY

562-1.2.1 DEFINITIONS. Some of the basic terms that apply to steering systems and system performance can be defined as follows:

a. Astern rudder operations - the use of the steering gear while the ship is moving in the reverse direction (backing down). On some ships, the astern speed, maximum rudder angle, or both are limited during astern operations so that the design rudder torque is not exceeded.

b. Autopilot - steering control equipment that allows the helmsman to enter a heading order for the ship. Electrical signals from the autopilot then automatically control the rudder angle so that the ship maintains the heading without the need for steering with a helm wheel.

c. Command angle - (also called the helm angle, helm order, or rudder angle order) the ordered or desired rudder angle that is input by the helmsman at the helm or differential control unit through manual operation of a helmwheel. When the system is operating in the automatic steering mode, the command angle is generated by the autopilot, instead of a helmwheel.

d. Dynamic rudder split - a condition where one rudder takes longer than (lags behind) a second rudder when the system is responding to a change in the command angle. A dynamic rudder split, sometimes referred to as rudder lag, only occurs on ships that have two or more independently-operate d rudders.

e. Follow-up - components within the steering system that follow the position of the hydraulic rams or rudder stock and send a mechanical or electrical signal to the controls that is in proportion to the actual rudder position. The follow-up provides a rudder position feedback signal to the control and nulls the pump output as the command angle is reached.

f. Hydraulic power unit - components of a hydraulic system that include the pump, electric motor, and other components needed to control the rudder.

g. Indicator split - a condition where the helm angle indicator and rudder angle indicators do not display the same angle even though the rudder is not moving. An indicator split can also occur when the rudder angle indicators do not display the same angle as the mechanical rudder angle indicator located near the rudder stock.

h. Nonfollow-up steering - a steering mode available on some ships that uses a type of joy-stick control to turn the rudder to the left or right. In this mode, the steering system does not position the rudder to an ordered angle.

i. Ram roll - a condition where the ram rotates slightly about its longitudinal axis as the rudder moves.

j. Rudder angle - the actual position of the rudder, measured in degrees from the zero (centered) position.

k. Rudder rate - the average speed the rudder moves during a hard-over to hard-over rudder swing while moving ahead at the maximum rated ship speed. Rudder rate is usually measured in degrees per second as the rudder moves from 35 degrees on one side of center to within 5 degrees of its maximum angle on the other side of center.

l. Static rudder split - a condition where the rudders of a ship do not stop at the same exact angle. A rudder split can only occur on ships that have two or more independently-operated rudders.

m. Steering modes - different methods of operating the steering gear. Some of the modes that are commonly available are normal, automatic, hand (electric), local (trickwheel), and emergency. A selector switch at the steering control console allows the helmsman to select the remote steering mode under normal conditions.

n. Steering station - the locations on the ship, usually the bridge and steering gear rooms, where the steering equipment can be controlled. Some ships, such as aircraft carriers, also have a secondary conning station.

562-1.3 SAFETY

562-1.3.1 GENERAL. Basic safety concepts cannot be over emphasized since safety hazards exist when operating or maintaining any electrical or mechanical equipment. All precautions should be followed when they apply to the type of test or maintenance being performed.

a. Voltages dangerous to life may be present. Do not work alone.

b. Ensure that all tag-out procedures are in accordance with current shipboard instructions.

c. In-port maintenance may require rudder activity. Every precaution should be taken to place ″Out of Service″ tags on controlling equipment and advise the appropriate personnel that work is being conducted in the vicinity of rudders.

d. Hazards to divers may arise from movement of the rudders. Confirm that there are no diving operations in the immediate vicinity and that there are no obstructions in the water that would interfere with the movement of the rudder(s).

e. Keep clear of moving equipment while the steering gear is in operation.

f. Do not wear loose clothing or neckties when working with moving machinery.

g. Avoid prolonged contact with, or inhalation of, cleaning solvents. Avoid use near heat or open flame and provide adequate ventilation.

h. Equipment temperatures may exceed 60°C (140°F). Do not handle heated parts. Use care when touching equipment piping.

562-1.3.2 ELECTRICAL. The following safety precautions should be followed whenever working with electrical equipment in the system.

a. Consider all electrical leads to be energized until positively proven they are deenergized.

b. Be alert at all times when using electrical equipment. The arc resulting from a short circuit or from a circuit opening under load may cause burns to hands or eyes more disabling than shock.

c. Only authorized personnel should operate or repair electrically driven machinery.

d. Avoid contact with uninsulated metal parts of electrical equipment, especially behind switchboards and within control cabinets, and power and lighting distribution boxes and fittings. Keep access doors to uninsulated electrical equipment closed.

e. Many casualties occur from faulty ground connections on portable equipment and failure to ground stationary equipment. All portable devices should be tested frequently to prove that a grounding circuit exists, from the metal frame of the device, through the grounding conductor in the cord, to the grounding contact in the attachment plug, and to ensure that high resistance insulation exists between the metal frame and all line contacts in the attachment plug. This test should be made after repairing portable equipment, and especially after replacing the attachment plug. Do not use portable equipment with a frayed cord or damaged plug. Report the condition to authorized personnel.

f. The frame of every stationary or semiportable electric device, which is not grounded by a grounding conductor, should be solidly grounded to the ship structure by first cleaning away all paint and rust where it is supported on the ship structure and then firmly attaching it by bolts or screws. Do not remove an electric device whose metal frame is normally grounded by contact with the ship structure without first opening the branch circuit switch. Otherwise, a fatal shock may result due to one of the line conductors making contact with the metal frame.

g. Do not service electrical equipment with power on.

h. Do not use noninsulated tools or metal rules, flashlights, etc., nor wear watches, rings, metal pencils, etc., when working on electrical equipment. Extreme care should be taken to avoid dropping metal tools or parts into electrical enclosures or mechanical devices.

i. Open the circuit switch before replacing fuses, and use insulated fuse pullers for removing and replacing fuses.

j. Do not work on electrical or mechanical devices without first opening the correct circuit breakers or positively determining that mechanical motion will not occur. All switches should be closed positively and rapidly.

k. Before working on a circuit or any electrically operated equipment, deenergize it using the correct circuit breakers and attach a red safety tag with an authorized signature to the open circuit-breaker handle. The circuit should then be tested with an approved voltage tester to prove that it is deenergized. Incandescent lamps should not be used for testing. Before working on circuits connected to capacitors or to high-voltage equipment, ground the conductors to discharge any static charge left. Use an approved shorting stick only. One is provided in each electrical/electronic space.

l. Only skilled personnel should work on live circuitry and mechanical equipment, and then only in extreme emergency, and by permission of a responsible officer. When working on a live circuit or mechanical equipment subject to movement, the following rules should be observed:
   1. Keep unauthorized persons away.
   2. At least two persons should work together, and both should be familiar with the method of resuscitation from shock and basic first aid techniques.
   3. Use rubber gloves and rubber-insulated tools, stand on rubber mats, and use one hand only.
   4. Exercise caution when walking in areas where oil is present. Remove oil spills or leaks as soon as possible to prevent injury from slipping and to eliminate fire hazards.

562-1.3.3 HYDRAULIC. The following precautions should be taken when installing, flushing, filling, testing, or performing maintenance on the hydraulic portion of the steering system.

a. Before breaking a hydraulic circuit connection, make certain all electric power is turned off and tagged ″Out of Service,″ and system pressure is released. Discharge pressure from line accumulators and block any load whose uncontrolled movement could cause pressure generation.

b. Ensure that the section of the system being worked on is completely depressurized and, if possible, drained. If possible, observe the pressure gage and carefully open a drain or vent valve to verify the proper operation of the isolation valves.

c. Ensure that under no circumstances will hydraulic fluid splash, drip, or spray on electrical and electronic equipment.

d. In breaking flanged joints, ensure that two diametrically opposite securing nuts or bolts remain tight while the remainder are slackened. The two remaining fasteners shall then be slackened just enough to permit breaking the joint and shall be removed only after the joint is broken sufficiently to prove that the line is unpressurized. If possible, the line should be drained before breaking the joint.

e. In the maintenance, disassembly, repair, and testing of hydraulic piping, follow the procedures and precautions set forth in **NSTM Chapter 505, Piping Systems** .

f. When testing after repairs, take the following precautions:
   1. Use a small-volume external pressure source (such as a hand pump) for hydrostatic tests. If use of an external source is not practical, crack open only the supply valve to the repaired section and continuously man the repair area until the repaired section is proven leak tight.
   2. If fluid spray could damage electrical equipment or create a fire safety hazard, protect reassembled mechanical joints by covering joints with spray shields or wrapping them with polyethylene bags.

g. Inspect all temporary hoses used for filling, flushing, or testing hydraulic piping systems to ensure there are no surface defects such as cracking or abrasions. Before use, subject temporary hoses to a shop hydrostatic test pressure of at least 110 percent of the maximum pressure that the hose will be subjected during the temporary use on the ship.

h. Do not use cadmium-plated parts in any hydraulic unit where they may come in contact with hydraulic oil. Cadmium reacts chemically with hydraulic fluid with detrimental results to system operation. This restriction does not prohibit the use of cadmium-plated parts such as nuts, bolts, and screws in locations that are external to the hydraulic unit if there is no danger of fluid contamination. Wash hands thoroughly after working with cadmium-plated tools or parts to avoid poisoning from ingestion of cadmium-contaminated food.

i. Observe all precautions to prevent fluid ignition or explosion during handling and stowage. See **NSTM Chapter 670, Stowage Handling, and Disposal of Hazardous General Use Consumables** .

j. Exercise caution when walking in areas where oil is present. Remove oil spills or leaks as soon as possible to prevent injury from slipping and to eliminate fire hazards.

k. Observe the following safety rules during the use or storage of cleaning agents for hydraulic components:
   1. Provide adequate ventilation.
   2. Always store new or used solvents in clearly labeled containers.
   3. Provide eye flooding and shower facilities as needed.
   4. Keep containers sealed when not in use.
   5. Avoid prolonged or repeated contact with the skin or breathing of vapors.
   6. Prohibit smoking, welding, or use of open flame in the vicinity of volatile or flammable solvents. Keep temperatures well below the flashpoint.
   7. Dispose of contaminated solutions in accordance with local safety regulations.
   8. Do not take solvents internally.
   9. Use protective devices such as cover or cup-type goggles, face shields, solvent-resistant gloves, and other protective clothing, as required.

Refer to **NSTM Chapter 262, Lubricating Oils, Greases, Hydraulic Fluids and Lubricating Systems** ; **NSTM Chapter 300, Electric Plant-General** ; **NSTM Chapter 556, Hydraulic Equipment (Power Transmission and Control)** ; and **NSTM Chapter 670** for further general precautions.

562-1.4 STEERING SYSTEM SPECIFICATIONS

562-1.4.1 MILITARY SPECIFICATIONS. MIL-S-17803, **Steering System, Electrohydraulic, Marine,** and MIL-S-17903, **Steering Control System, Naval Shipboard Use,** are the appropriate military specifications for large Navy surface ship steering systems.

SECTION 2.

FUNCTIONAL CHARACTERISTICS

562-2.1 STEERING SYSTEM FUNCTION

562-2.1.1 GENERAL. A ship is steered by the force of the water acting on the rudder as the ship moves through the water. The function of the steering system is to control the position of the rudder against the force of the water. Rudder control involves turning the rudder to the left or right to a desired angle in degrees, and holding the rudder in position.

562-2.2 RUDDER CONTROL

562-2.2.1 TORQUE. The force from the water on the rudder creates a torque on the rudder stock. The magnitude and the direction of torque acting on the rudder stock are not constant. Torque varies with changes in the rudder angle and is affected by ship speed and sea state. The steering system adapts to these changes in torque by producing enough countering torque on the rudder stock to control the position of the rudder.

562-2.2.2 RUDDER TORQUE CURVES. A rudder torque curve shows the estimated rudder torque at the maximum ship speed for a particular ship. A typical rudder torque curve is shown in Figure 562-2-1. The maximum torque value is the basis for determining the sizes of the rudder actuator and the steering gear power units. The negative and positive regions of the graph indicate the direction that torque is applied to the rudder stock. For most Navy ships, the rudder torque direction changes at the 0 degree rudder angle and at a 25 degree (approximate) rudder angle. For these ships, the rudder has a natural tendency to travel to the 25 degree position, left or right of center. When the rudder torque is negative, the steering gear applies torque in the direction opposite the direction of rudder travel. In this way, the steering gear counters the natural rudder motion so that it can hold the rudder at the command angle and control the rate of rudder travel. When the rudder torque is positive, the steering system applies torque in the same direction as the rudder travel. At small rudder angles, the forces from the water flow on the rudder tend to rotate the rudder left or right away from the zero rudder angle, creating some instability. The instability is caused by the change in torque direction at zero degrees and the tendency of the rudder to seek the 25 degree rudder angle on either side of center. The instability is not seen at the 25 degree rudder angle because the rudder is not seeking to move away from this position.

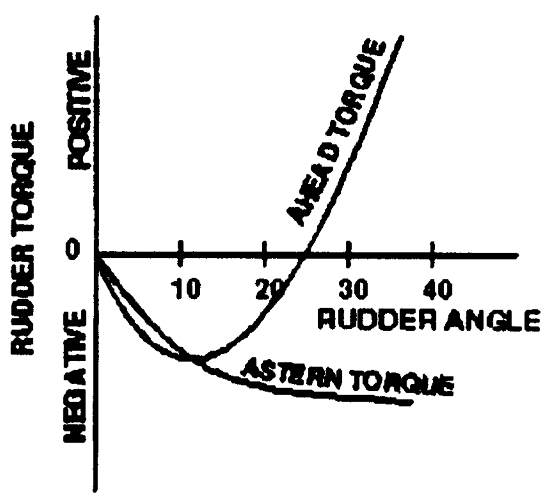


Figure 562-2-1 Typical Rudder Torque Curve

562-2.2.3 ASTERN LIMITS. When the ship is moving in reverse (backing down), the force of the water on the rudder tries to move the rudder away from center. The design and shape of the rudder affect the loads and the torque acting on the rudder and steering system. For some rudder designs, the loads are similar for forward and astern operations. For other designs, the loads for astern operations are significantly higher. To control the rudder at high astern ship speeds, these steering systems would need much larger power units. Instead of adding excess weight to the steering system strictly for astern operations, the maximum allowable ship speed that can be used for astern operations is limited. The slower ship speeds reduce the maximum torque on the rudder stock and the power needed from the steering system to control the rudder. These limits are determined during sea trials and are posted on the ship control console and in the steering gear room. Table 562-2-1 lists the astern limits for several, but not all, ship classes. Any limits posted on the ship control console or in the steering gear room should be strictly followed.

Table 562-2-1 LIMITS FOR ASTERN RUDDER OPERATIONS FOR SOME SHIP CLASSES

Ship Class	**Astern Limits**
ARS 8, 38-43	Note to exceed standard rudder when backing at 2/3 speed (100 rpm) or 10 degrees rudder when backing at greater than 2/3 speed.
CG 16-24, 26-34	Maximum speed 14 knots and rudder angle not to exceed 10 degrees.
AS 36, 37	Maximum shaft speed 80 rpm and unlimited rudder angles.
CG 47, DD 963, DDG 993 classes	Maximum shaft speed 110 rpm and unlimited rudder angle.

562-2.3 RUDDER POSITIONING

562-2.3.1 RUDDER POSITIONING ACCURACY. When operating properly, the steering system will position the rudder(s) to the command angle. At times the steering system may begin to show some difference between the command angle and the rudder position. The differences are the degrees of error. Steering systems with new or overhauled follow-up assemblies are required to have a mechanical comparative error of not more than ±1/4 degree from 0 to 5 degrees of rudder angle and ±1/2 degree for any rudder angle greater than 5 degrees. This comparative error requirement is based on measurements taken at the rudder angle indicator on the mechanical differential steering stand and the mechanical rudder angle indicator on the tiller or rudder actuator. Some steering systems have numerous gears and linkages in the follow-up mechanism and have difficulty meeting these accuracy requirements, especially after having been in service for a long period of time without an overhaul. Accuracy is affected by lost motion in each of the gearboxes and pivot joints, and by the sensitivity of the pump servo control valve. For these systems, realistic accuracy requirements are a comparative error of not more than ±1/2 degree from 0 to 5 degrees of rudder angle and ±1 degree for any rudder angle greater than 5 degrees. Conditions exceeding these values require corrective action.

562-2.3.2 REMOTE RUDDER ANGLE INDICATOR ACCURACY. An error of up to 2 degrees is allowed when comparing the rudder angle indicated on the ship control console, or other remote electrically-operated indicators, with the mechanical rudder angle indicator in the steering gear room.

562-2.3.3 INDICATOR SPLIT. An indicator split is a condition where the helm angle indicators and the rudder angle indicators do not display the same angle even though the rudder is not moving. An indicator split can also occur when the rudder angle indicators do not display the same angle as the mechanical rudder angle indicator located near the rudder stock. Indicator splits can be caused by lost motion or misalignment of the follow-up mechanism or by problems with indicator calibration. Indicator splits should be corrected when they exceed the rudder positioning accuracy or remote rudder angle indicator accuracy requirements of paragraphs 562-2.3.1 and 562-2.3.2.

562-2.3.4 OVERTRAVEL AND OVERSHOOT. Steering systems may experience positioning problems such as overtravel and overshoot. Overtravel is a condition where the steering system positions the rudder beyond the command angle and the rudder remains at that position. Overshoot is a condition where the steering system turns the rudder beyond the commanded angle then reverses direction to position the rudder where it should have stopped. The steering system should be adjusted to correct these conditions (see paragraph 562-2.3.1).

562-2.4 RUDDER TRAVEL

562-2.4.1 RUDDER RATE. Rudder rate is a design criteria for the steering system that is based on the maneuvering performance requirements of the ship. Rudder rate is the average speed that the steering system rotates the rudder under full power and full pump output conditions. To determine the rudder rate, a hard-over to hard-over command is given while the ship is moving ahead at the maximum rated ship speed. Timing begins when rudder motion begins and ends when the rudder reaches 30 degrees (or 5 degrees before hard-over) on the other side of center. The final 5 degrees of rudder swing are not used in determining rudder rate because the steering system slows the rudder as it approaches the command angle. When rudder rates are tested pierside, the steering system is not under full power conditions. Consequently, the measured rudder rates are approximately 5 to 10 percent faster than when tested underway.

562-2.4.2 DYNAMIC RUDDER SPLIT. Dynamic rudder split is a condition where one rudder takes longer than, or lags behind, a second rudder when the system responds to a change in the command angle. Dynamic rudder split is apparent during rudder rate timing and when observing the rudder angle indicators for both rudders. This condition can only occur on ships with independently-operated rudders. If a dynamic rudder split is suspected to be a problem, a rudder rate timing test should be conducted in accordance with Preventive Maintenance System (PMS) requirements. A maximum permissible rudder split should not be greater than 5 degrees. The test determines whether each rudder rate is within the allowable tolerances for the particular system. If the rates are not within the acceptable tolerances, the system should be adjusted.

562-2.4.3 STATIC RUDDER SPLIT. Static rudder split is a condition where the rudders of a ship do not stop at the same exact angle. This condition can only occur on ships with independently-operated rudders. When the rudders are not moving, the difference between the two rudder angles should not exceed 1 degree for rudder angles between 0 and 5 degrees, and should not exceed 2 degrees for any rudder angles greater than 5 degrees. If the rudder split exceeds these conditions, the steering system should be adjusted.

SECTION 3.

STEERING SYSTEM CONFIGURATIONS

562-3.1 OVERVIEW

562-3.1.1 GENERAL. Steering systems share many features among different ships and ship classes, but they are not all identical. Differences among steering system configurations are the result of different ship requirements and design parameters. The rudder torque, the maximum rudder angle, the size of the steering gear room, and the location of the rudder stock are factors that affect what components are used in a steering system design. This section describes some of the equipment variations that can be found among ship classes. Interfaces with other shipboard systems are identified.

562-3.2 TYPES OF SYSTEMS

562-3.2.1 ELECTROHYDRAULIC SYSTEMS. With few exceptions, surface ship steering systems are electrohydraulic. Electrohydraulic steering gears use an electrical control system to control and monitor a hydraulic system. The hydraulic system positions the rudder. This chapter focuses on this type of system.

562-3.2.2 ELECTROMECHANICAL SYSTEMS. Electromechanical steering gear systems may be found in some older and smaller ship classes. These systems have electrically driven components and operate without hydraulic pumps. Electromechanical systems, no longer in widespread use, are not covered in this chapter.

562-3.3 TYPES OF COMPONENTS

562-3.3.1 GENERAL. Electrohydraulic steering systems consist of hydraulic, control, follow-up, and emergency equipment. The hydraulic system includes the rudder actuator, the hydraulic power units (HPUs), and supporting hydraulic equipment. The electrical control system consists of helm wheels, cables, switchboards, differentials, pump stroke operators, and other components. A follow-up system joins the machinery to the controls, continuously signaling the current rudder position to the control system. In the event of a failure of the main system, emergency steering systems are available on each ship.

562-3.3.2 HYDRAULIC EQUIPMENT. Steering systems use hydraulics to control the rudder because of the high torque to weight ratio provided by these systems. The hydraulic equipment is located in the steering gear compartments close to the rudder stock to minimize pressure drops. Pumps, valves, filters, tanks, and piping are some of the basic components found in all steering systems. System configurations vary in the type of rudder actuator, pump control, location of specific components, size of the equipment, and other areas.

562-3.3.2.1 Rudder Actuators. The following types of rudder actuators are used on surface ships:

a. Rapson-slide

b. Link and tiller

c. Rotary (vane)

d. Clevis-mounted cylinders

The Rapson-slide and the link and tiller actuators are the most common. The type of actuator installed on a particular ship depends largely on the amount of torque needed to turn the rudder and the space available in the steering gear room.

562-3.3.2.2 Hydraulic Power Units (HPUs). HPUs provide the hydraulic power needed to control the rudder. Every HPU has a main pump and an electric motor. Most HPUs have similar types of components including auxiliary pumps, distributor valves, tanks, accumulators, and oil coolers. Differences between the HPUs of different ship classes are not always obvious. Systems vary in the size or capacity of the components, type and location of the fluid tanks, and other areas.

562-3.3.3 STEERING CONTROLS. Steering control equipment is located on the bridge, in the steering gear room, and at other remote locations according to ship requirements. Bridge equipment is integrated into the ship control console. Steering control equipment can be categorized into:

a. Hand (electric)

b. Telemotor

c. Digital

Hand (electric) is the most commonly used system and can be found on aircraft carriers, destroyers, frigates, oilers and support ships. Telemotor systems are not very common but they can be found on older auxiliary ships. Digital control systems are the most recently designed steering control system and are installed on DDG 51 Class ships.

562-3.3.4 RUDDER POSITION FEEDBACK SYSTEMS. The follow-up system links the steering machinery to the controls. This system is part of the rudder position feedback system. The follow-up is connected to the rudder stock or rudder actuator and operates continuously. Follow-up systems are either mechanical or electrical. Examples of mechanical follow-up systems include the helix screw with cam follower and cable systems. Mechanical follow-up systems are used with rudder angle synchro transmitter units. These units transmit the rudder position to remote indicators throughout the ship. Electrical follow-up systems, found on the DDG 51 and AOE 6 ship classes use a potentiometer assembly to signal the rudder position to the steering controls and remote rudder angle indicators.

562-3.3.5 EMERGENCY EQUIPMENT. Every steering system is equipped with at least two methods of controlling or positioning the rudder in the event of a main system failure. Emergency equipment includes electrically powered pumps, hand pumps, ratchet wrenches, and chain falls. The electrically powered pumps and the hand pumps provide rudder movement at lower rates than the main system. The ratchet wrenches and chain falls are intended only for maintaining a rudder position or moving the rudder one or two degrees while the ship is not moving. The type of emergency equipment and the configuration of the equipment varies among different ships or ship classes.

562-3.4 REDUNDANCY

562-3.4.1 FEATURES. Redundancy and survivability features are designed into every system so that alternate means of rudder control are available in the event of a failure. Dual power units are provided for each actuator. A minimum of two steering stations, the bridge and after steering, are available on each ship. Aircraft carriers also have secondary conning stations. The control system has duplicate synchro transmitters and receivers, cabling, and other components. Additionally, the components are separated to the maximum extent practicable to enhance steering system survivability. Steering systems are designed to minimize single failure points. Single failure points are those components or locations in the system where a failure can lead to loss of rudder control. Examples of single failure points are the cylinders and cylinder piping. These components have stringent design requirements so that the likelihood of failure is minimal.

562-3.5 COMPONENT CONNECTIONS

562-3.5.1 TYPICAL ARRANGEMENTS. Figure 562-3-1 and Figure 562-3-2 are block diagrams of typical hand (electric) and digital steering control systems. Figure 562-3-3 shows a typical steering machinery arrangement. These figures are presented as guidance in understanding how the steering equipment is connected. The type of equipment, number of rudders, number of steering gear rooms, and other factors affect the actual system configuration.

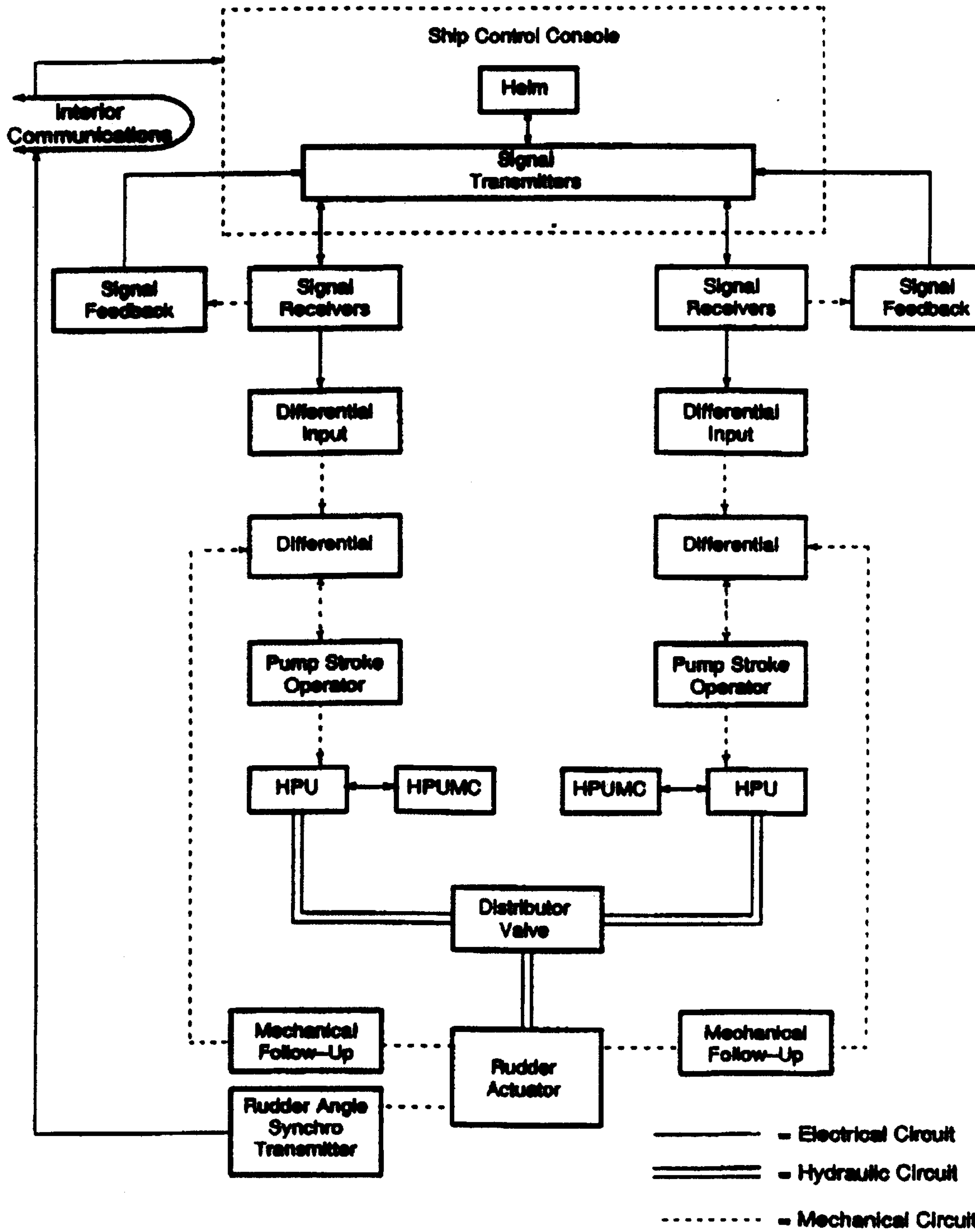


Figure 562-3-1. Typical Component Connections for a Hand (Electric)Steering System

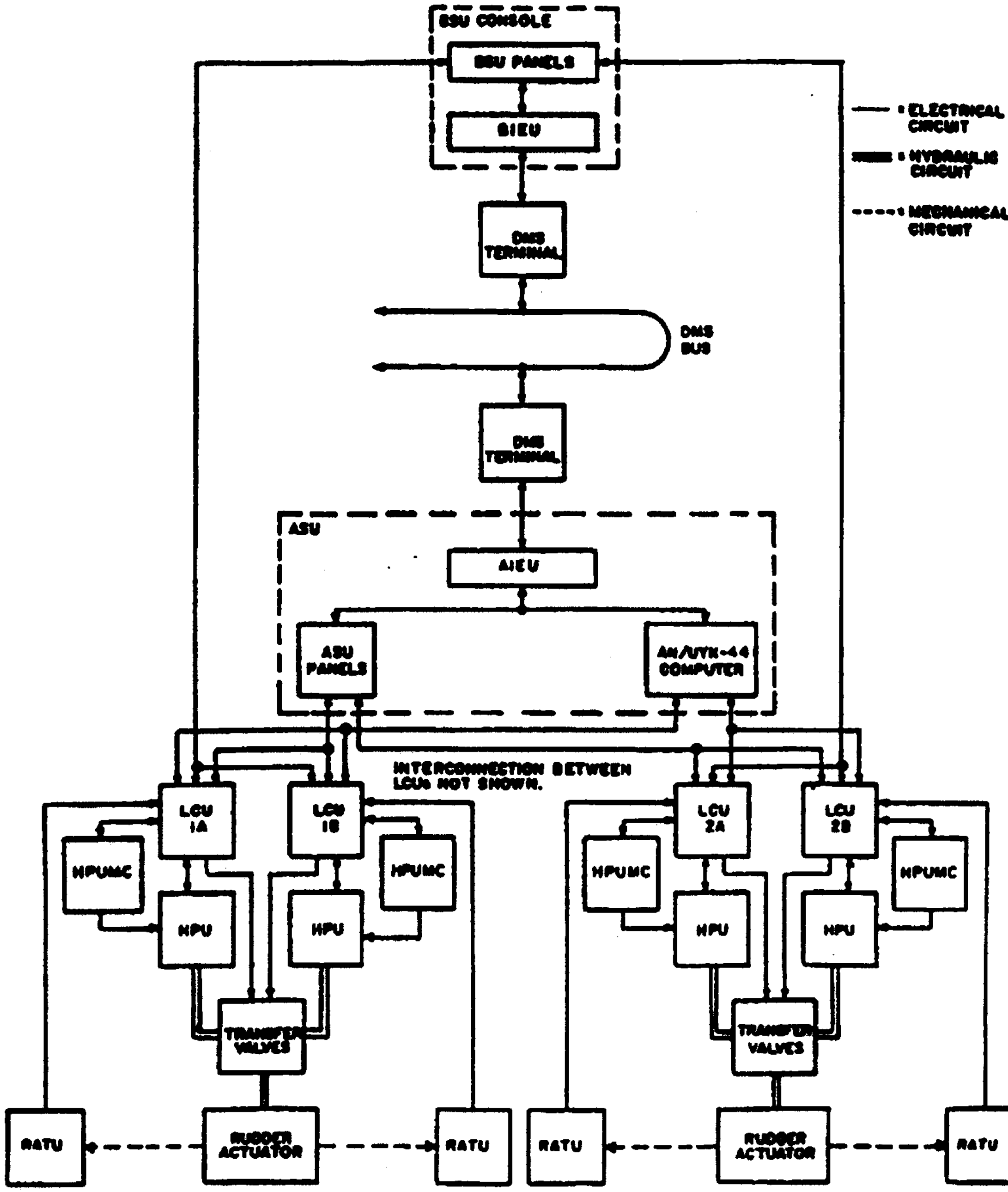


Figure 562-3-2 Typical Component Connections for a Steering System with a Digital Controller

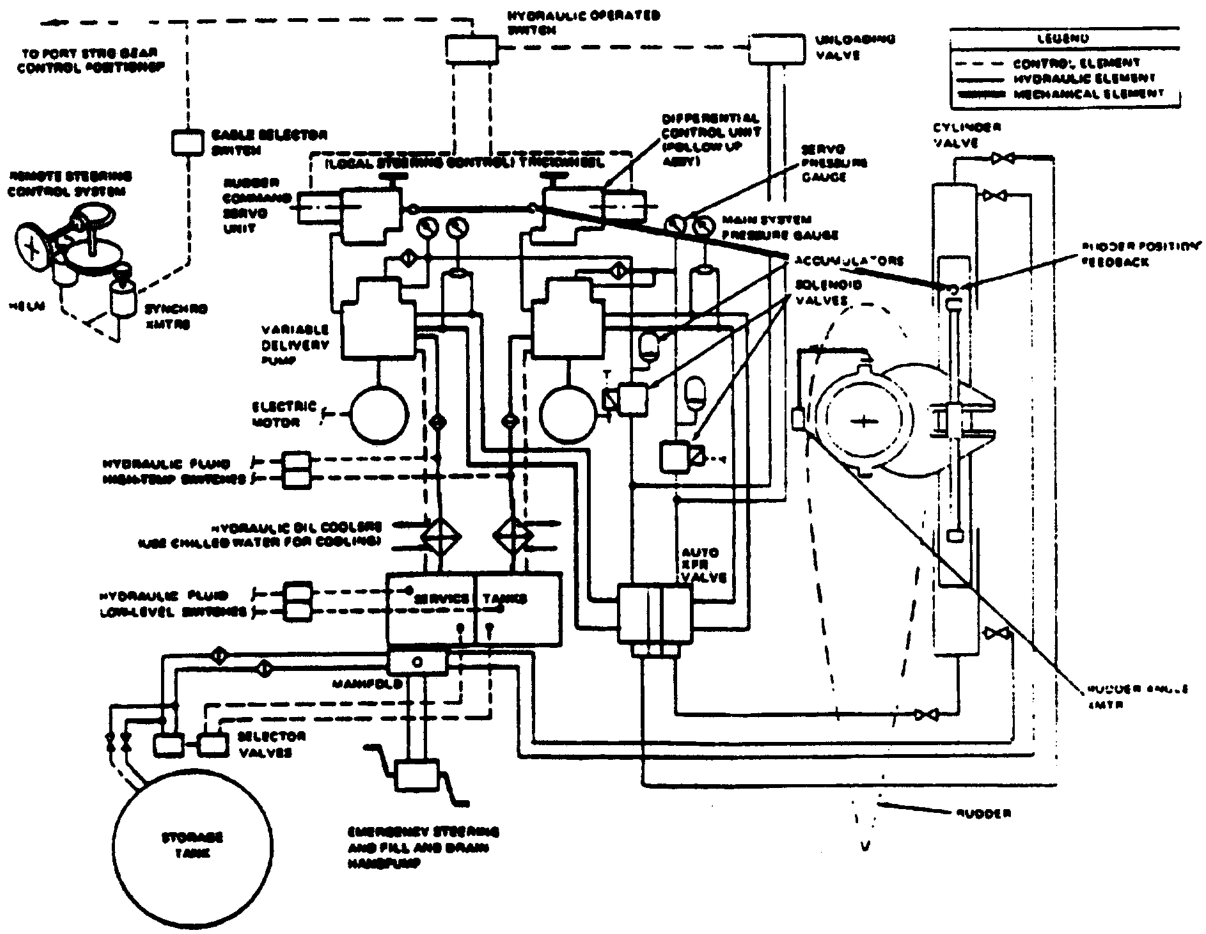


Figure 562-3-3. Typical Component Connections of Steering Machinery

562-3.6 SYSTEM INTERFACES

562-3.6.1 GENERAL. The steering system interfaces with other shipboard systems. Steering relies on signals from the Interior Communications System, electrical power from the distribution system, and cooling water from the auxiliary system.

562-3.6.2 INTERIOR COMMUNICATION. The interior communication system provides ship heading and ship speed information from the main gyrocompasses to the steering control system. The underwater log provides ship relative speed inputs, as generated by water forces, to the ship speed indicators. Course-to-steer information from the command and decision system is also used during steering operations. A rudder angle synchro transmitter, mechanically linked to the rudder stock, transmits the actual rudder position to stations throughout the ship. This transmitter is independent of the mechanical follow-up system which provides a rudder position feedback signal to the steering differentials. Sound-powered telephones and dial telephone service between the steering gear room and the bridge are also a part of the Interior Communication System.

562-3.6.3 ELECTRICAL POWER. Electrical power to operate and control the steering system is supplied by the ship service/emergency power distribution system. The power distribution system supplies 440 V, 60 Hz, 3-phase power to the motor controllers. The power for steering control components located in the ship control console is supplied by the same source that powers the ship control console, usually the lighting distribution system. Single phase power is supplied to the steering control switchboard for local alarm and monitoring circuits.

562-3.6.4 COOLING WATER. Cooling water from the chilled water system or the sea water system is piped to the steering gear to provide cooling water flow through the oil coolers. The interfacing system depends on what is available on the ship. Chilled water systems provide a fairly constant water temperature while the temperature of sea water systems varies according to the outside water temperature.

562-3.6.5 RUDDER STOCK AND BEARINGS. The rudder stock and bearings have an effect on the design and operation of the steering equipment. The rudder stock is attached to the rudder and is supported by upper and lower bearings within the ship hull. The upper rudder stock bearing and rudder carrier rings support the weight of the rudder, rudder stock, and all components directly attached to the rudder stock. The lower bearing absorbs radial loads. Rudder bearings are covered in **NSTM Chapter 243, Propulsion Shafting** .

SECTION 4.
HYDRAULIC EQUIPMENT

562-4.1 TYPES OF HYDRAULIC EQUIPMENT

562-4.1.1 DESCRIPTION. Hydraulic equipment includes the rudder actuators, power units, piping, tanks, and other components that produce the hydraulic power needed to control the rudder under normal conditions. Although some emergency systems are hydraulic, these components are discussed in Section 6. On most ships, the hydraulic steering equipment is located in the steering gear room. The power units are mounted near the rudder stock to minimize the pressure drop in the piping between the power units and the rudder actuator.

562-4.2 RUDDER ACTUATORS

562-4.2.1 RAPSON-SLIDE. In the Rapson-slide actuator (Figure 562-4-1), a ram is centered between a fork-shaped tiller. A ram pin assembly connects the two components. Variations in configuration are found in CV 59-63 class steering gear systems. During operation, the hydraulic system pumps fluid into one of the cylinders. The pressure in the cylinder increases and exerts a force on the end of the ram causing it to move. As shown in Figure 562-4-2, the linear motion of the ram transmits force through the ram pin to the sliding blocks. The sliding blocks engage the tiller causing the tiller to rotate. The rotation of the tiller rotates the rudder. The geometry of the Rapson-slide allows the steering system to produce higher torques with increasing rudder angles. Since the torque required to turn the rudder increases as the rudder moves away from the center position, the Rapson-slide is ideally suited for steering systems. When extremely high torque is needed, two rams on opposite sides of the rudder stock operate the rudder. The major components of this actuator are the tiller, ram, ram pin assembly, and cylinder.

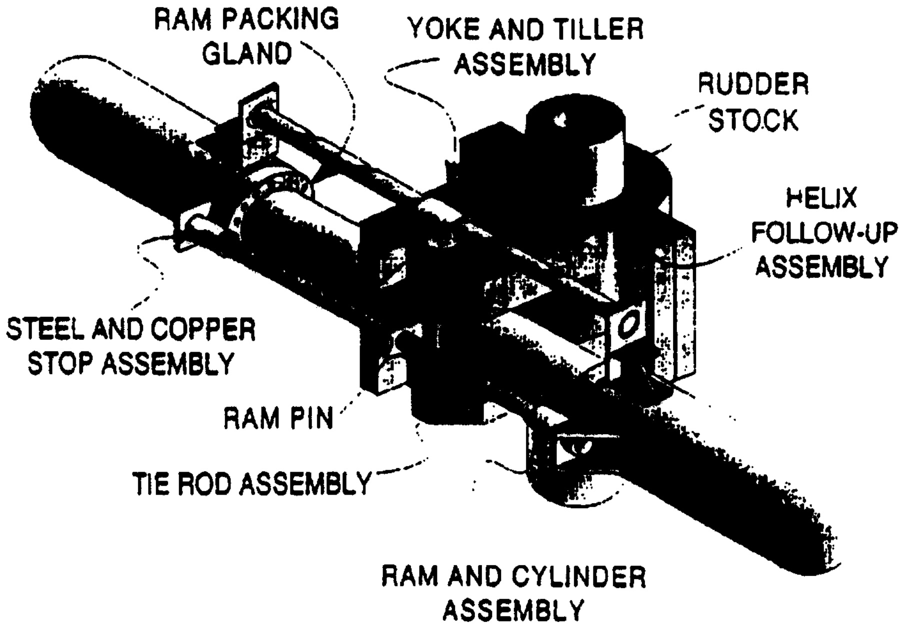


Figure 562-4-1 Rapson-slide Assembly

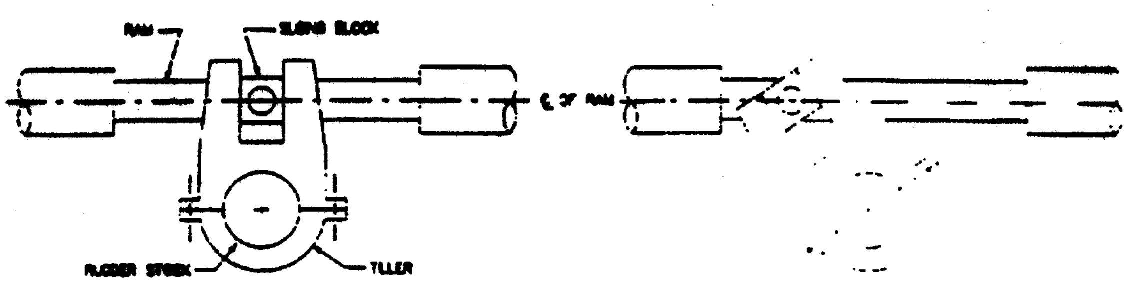


Figure 562-4-2 Motion of the Rapson-slide

562-4.2.1.1 Tiller. The tiller is a two piece casting that clamps around the rudder stock. The two halves are fastened together by large-diameter nuts and bolts. Each piece is keyed to the rudder stock to prevent the tiller from sliding around the rudder stock as the rudder turns. One hub is semicircular; the second hub, called the crosshead or the yoke, has two, two-prong forks that line up with a vertical pin extending through the ram. When two rams operate a rudder, two crosshead pieces are used for the tiller. The inside surfaces of the upper and lower forks of the crosshead are perfectly inline. This ensures that the tiller will transmit forces equally between the two forks.

562-4.2.1.2 Mechanical Rudder Angle Indicator. Each rudder has a mechanical rudder angle indicator mounted on or near the rudder stock. The indicator consists of a pointer and a scale. One component is secured to the ship’s structure and the other component turns with the rudder. Graduations on the scale show the exact rudder position at all times. The indicator is used during emergency steering operations to show the true rudder position. The indicator is also used to determine the accuracy of all other rudder angle indicators on the ship. It serves as a reference when calibrating these remote indicators.

562-4.2.1.3 Ram. The ram acts as a double-acting piston. It is mounted between two opposing hydraulic cylinders aligned perpendicular to the rudder stock. The center of the ram is rectangular with a vertical hole drilled for a large pin (approximately 5 to 6 inches in diameter). When installed, the pin extends equally above and below the ram. Crosshead blocks fit over the pin extensions to provide a bearing between the crosshead of the tiller and the ram pin. The center of the ram supports the upper crosshead block and acts as a mating surface for the lower block. A stop block (Figure 562-4-3) mounted to the front of the ram houses a bushing that rides along a tie rod. A small lubrication fitting on the front of each stop block is used to grease the bushing. The tie rod, part of the cylinder assembly, connects the two hydraulic cylinders and prevents the ram from rotating within the cylinders. Some larger systems have two stop block and tie rod assemblies on the ram. The sliding stop block contacts positive stops adjacent to the cylinders that limit the travel of the ram and prevent the ram from bottoming on the ends of the hydraulic cylinders. The tie rod and stop block can also be used to mechanically hold the rudder in a particular position.

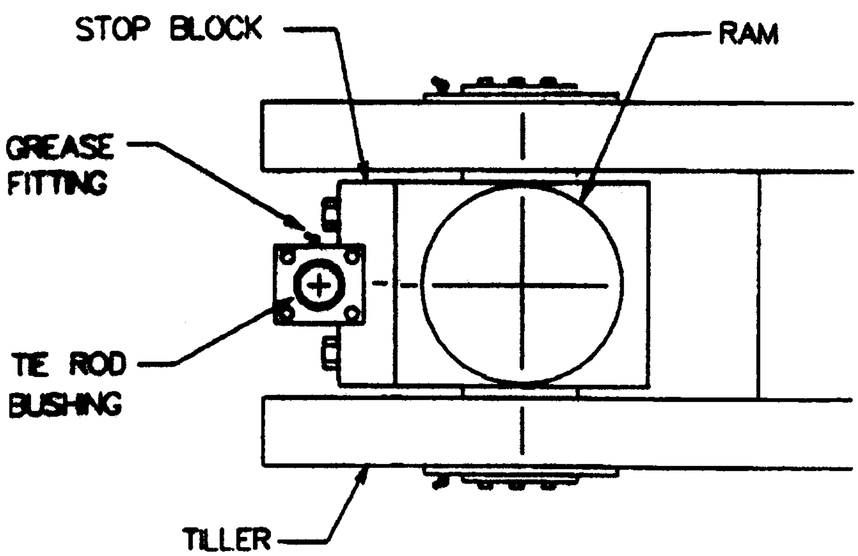


Figure 562-4-3 Stop Block and Tie Rod Bushing Assembly

562-4.2.1.4 Ram Pin Assembly. The ram pin assembly is the interface between the ram and the tiller. It consists of the ram pin, crosshead blocks, and pin plates as shown in Figure 562-4-4.

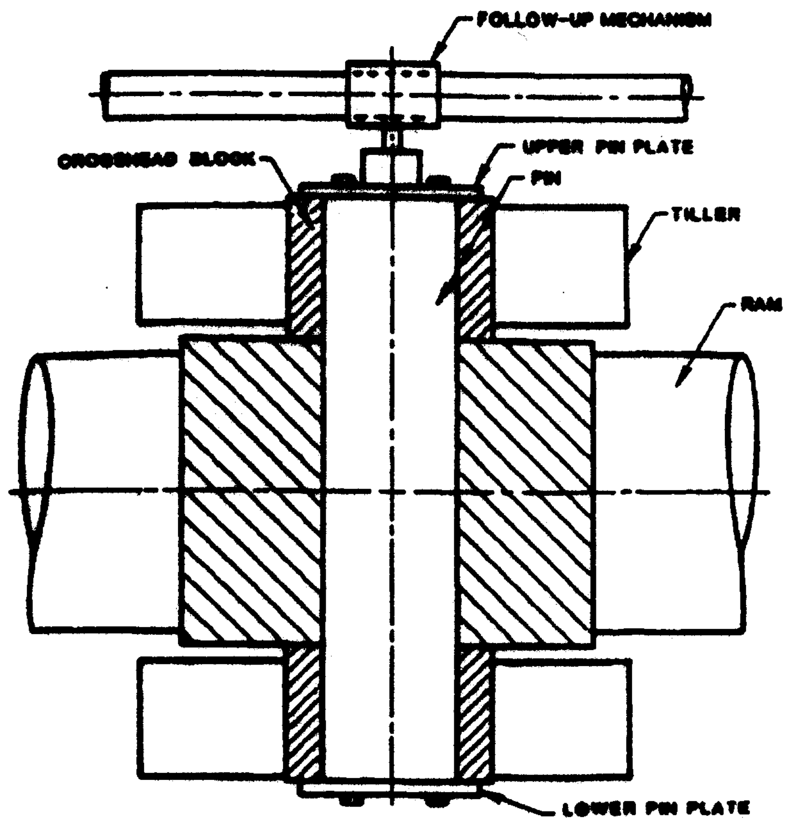


Figure 562-4-4 Ram Pin Assembly

562-4.2.1.4.1 Ram Pin. The ram pin, also called the trunnion, is a solid metal cylinder positioned vertically in the ram. The clearance between the pin and ram varies from ship to ship. Some pins have a loose fit that allows the pin to drop through the hole. Others have an interference fit that requires close tolerances and cooling the pin in liquid nitrogen before installing. Still other pins have been permanently positioned in the ram with an anaerobic compound such as Loctite. In most cases the pin will not rotate as the ram moves. Holes are drilled at the ends of the ram pin for fastening pin plates.

562-4.2.1.4.2 Crosshead Blocks. Crosshead blocks, also called sliding blocks, are bronze bearings that fit over the ends of the ram pin. Two outside surfaces of the block contact the tiller forks and slide along the inside surfaces of the fork. The large-diameter hole drilled through the center of the block rotates around the ram pin as the ram moves. Grease fittings on the crosshead blocks allow for lubricating the surfaces in contact with the pin and tiller forks without removing the crosshead blocks. The dimensions and machining tolerances of the crosshead blocks are important to the operation of the Rapson-slide since the blocks transmit the forces between the ram and the tiller. To divide the forces equally between the upper and lower forks, both sliding blocks must contact the tiller and the ram pin. The edges must be square, the block must be the specified dimensions for the tiller, and the hole for the pin must be centered within the blocks and perpendicular to the sides.

562-4.2.1.4.3 Pin Plates. Pin plates are metal plates fastened to the ends of the ram pin. The upper pin plate prevents the pin from dropping through the ram should the pin have a loose fit. In some steering systems the upper pin plate is part of the follow-up system. (Follow-up systems are discussed in Section 5.) The lower pin plate supports the lower crosshead block and prevents it from falling from the assembly. Pin plates are attached to the ends of the ram pin with fasteners. Each system may be slightly different in the number, size, and type of fasteners. In all cases, the fasteners are either lockwired or installed with inserts to prevent them from loosening.

562-4.2.1.5 Cylinders. The hydraulic cylinders are mounted to the foundation, perpendicular to the rudder stock and inline together. The ends of the cylinders may be either flat or hemispherical. The cylinders hold the ram and are connected by one or two tie rods. Flanges join each cylinder to the hydraulic system piping. Packings installed at the openings of the cylinders prevent hydraulic fluid leakage and maintain a protective film of hydraulic fluid on the ram. A small bleeder valve at the top of each cylinder is for removing air that becomes entrapped in the cylinder during operation. Components of the cylinder assembly include packings, bushings, tie rods, foundation fasteners, and stops.

562-4.2.1.5.1 Packings. V-ring packings, also called chevron packings, act as a seal between the ram and the cylinders. Although several types of seals exist, V-ring packings are one of the few that can be split to allow the seals to be replaced without removing the ram. Steering systems use the outside packed installation shown in Figure 562-4-5. The outside edge of the packing contacts the inside cylinder wall while the inside edge of the packing contacts the ram. The V-ring packing is actually a packing set, or stack, that includes a male adapter, several V-rings, and a female adapter. The adapters are in sections and the packing rings are cut for installing and removing them with the ram in place. The packing set is located in a cavity within the cylinder wall. This cavity, called a packing gland or stuffing box, contains and supports the packing around the ram. The male adapter is installed furthest into the cylinder. The flat edge rests against the bronze bushing and the point of the solid V faces the cylinder opening. The bushing within the cylinder supports the weight of the ram and any side loads from the Rapson-slide to avoid damaging the packings during operation. The V-rings are installed over the male adapter so the opening of the V-ring faces the inside of the cylinder and the point of the V faces the cylinder opening. The cuts in the V-rings are staggered 180 degrees, then 90 degrees, then 180 degrees, and so on. The staggering prevents the cuts in the rings from providing a flow path for leakage. The female adapter slides over the V-rings with the hollow part of the V placed over the packing and the flat edge facing out. The flat edge provides a mating surface for the gland seal retainer ring. The gland seal retainer ring is fastened to the cylinder end and actually holds the packing set in place. A wiper and a retainer for the wiper, installed over the gland seal retainer ring, keep dirt from entering the system. On most systems the packing gland is adjustable. The necessary clearance or squeeze is obtained by tightening down or loosening the positioning nuts holding the gland seal retainer ring. An even gap should always exist between the cylinder and the lip of the gland seal retainer ring. After all adjustments are made, locknuts are installed over the positioning nuts to hold the positioning nuts in place. When the moving seal changes direction during operation, a very slight amount of fluid can escape. This fluid lubricates the V-ring stack and maintains a film of oil on the ram. The ideal situation exists when seepage is sufficient to lubricate the seal without excessive system fluid or pressure loss. In addition to checking the ram for a uniform, light oil film along its surface, maintenance personnel should also check the ram for scoring and pitting. Scoring can be caused by foreign particles embedded in the packing. The particles can produce grooves or ridges that can result in packing wear and increased oil leakage. Pitting and subsequent packing wear can be caused by excess moisture deposits and rust. Scoring and pitting become significant when either can catch a fingernail passing in contact with it. The corrective action is to remove the cause of the scoring or pitting and replace the packing. **NSTM Chapter 078, Volume 2, Gaskets and Packings** provides more information on V-ring packings.

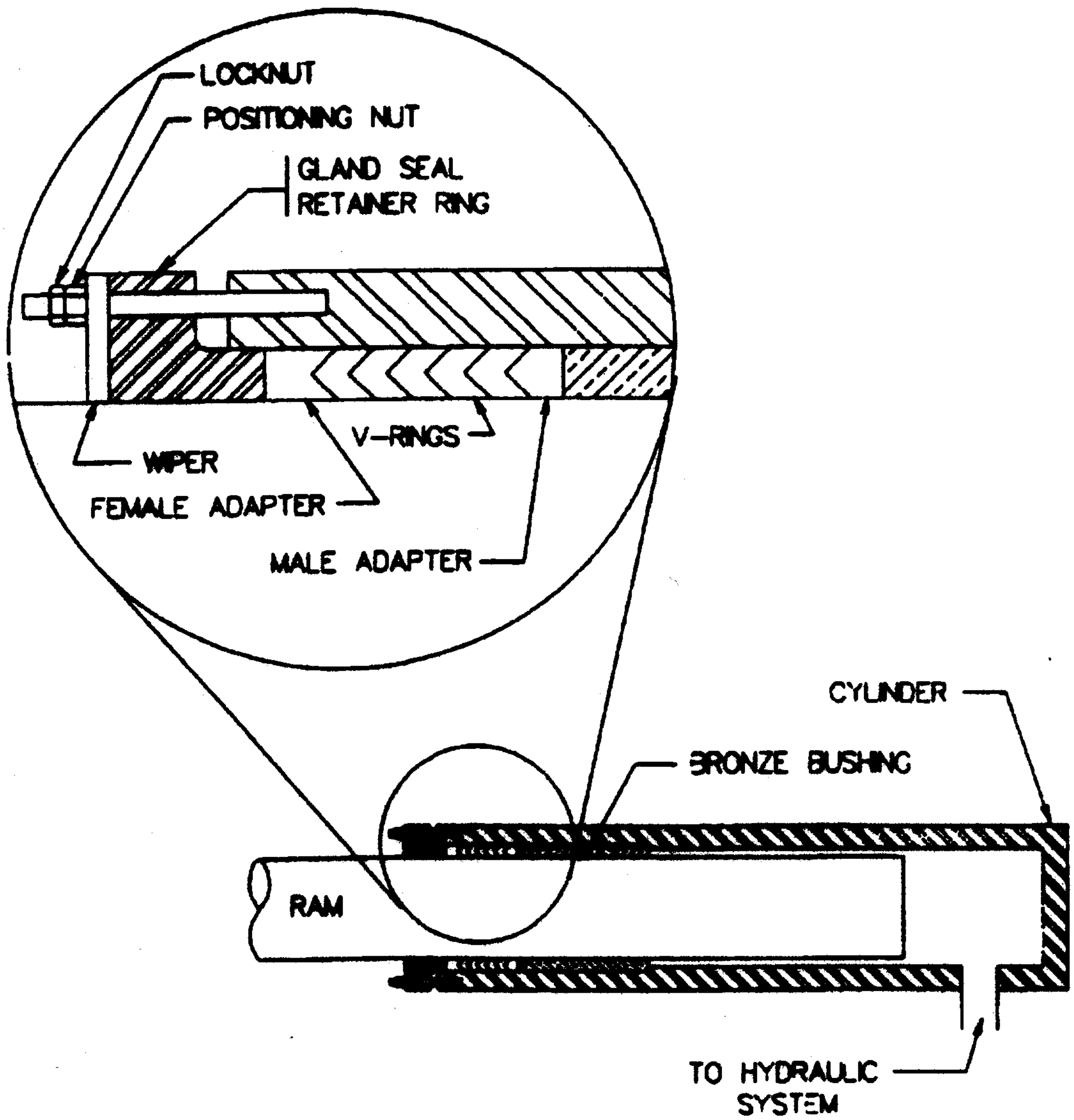


Figure 562-4-5 Outside Packed V-ring Installation

562-4.2.1.5.2 Bushings. Bronze bushings within the cylinders support the ram as it moves and act as a bearing against the side loads that result from the Rapson-slide configuration. A counterbore within the cylinder holds the bushing. Bushings wear over time, leaving bronze particle sediment in the bottom of the cylinders. This sediment does not harm the system unless it becomes entrained in the fluid that circulates through the pump. If the sediment is dispersed into the system it can cause wear on the components and degrade performance.

562-4.2.1.5.3 Tie Rods. Tie rods are threaded rods that connect the opposing cylinders. Systems can have either one or two tie rods on each cylinder assembly. The rods, which are mounted to the side of the cylinders, are a specified length to help position the cylinders at installation. The tie rod connects to the ram through a stop block on the side of the ram. The stop block contains a bushing that rides along the tie rod and helps prevent the ram from rotating. Jacking nuts on the tie rod can be positioned against the stop block to hold the rudder in place in an emergency.

562-4.2.1.5.4 Foundation Fasteners. The fasteners that hold the cylinders to the foundation are fitted at installation when the cylinders are precisely aligned. Each fastener has a specific location for the life of the gear.

562-4.2.1.5.5 Overtravel Stops. Each cylinder has one or more sets of stops. Each set consists of a copper stop and a steel stop. The stops can be mounted on either the tie rods or the cylinder. The Rapson-slide shown in Figure 562-4-1 has overtravel stops mounted on the tie rod. Copper stops, or crushing pieces, are closest to the center of the assembly so the stop block on the front of the ram will hit the copper stop before hitting the steel stops. The crushable copper stops deform upon impact, cushioning the impact of the ram crosshead on the steel stops. Positive steel stops, or hard stops as they are sometimes called, mounted behind the copper stops positively limit the travel of the rudder and prevent the ram from bottoming on the cylinder. The steel stops transmit the load of the rudder to the foundation.

562-4.2.2 LINK AND TILLER. The link and tiller steering system (Figure 562-4-6) uses a single ram to operate two rudders. Large pins join the links to the ram and tillers. As the ram moves, both rudders turn simultaneously. The links and pins compensate for the arc-shaped motion of the tillers without sliding blocks or forks. Unlike the Rapson-slide, the link and tiller does not have a mechanical advantage at larger angles. The torque produced decreases with increasing rudder angles. The rams are sized to develop sufficient force at the maximum rudder angle. The major components of this actuator are the tillers, ram, links, and cylinders. With the exception of the links, these major components are similar to those of the Rapson-slide. Refer to paragraphs 562-4.2.1.1 to 562-4.2.1.5.5 for a more indepth description of the ram and cylinders.

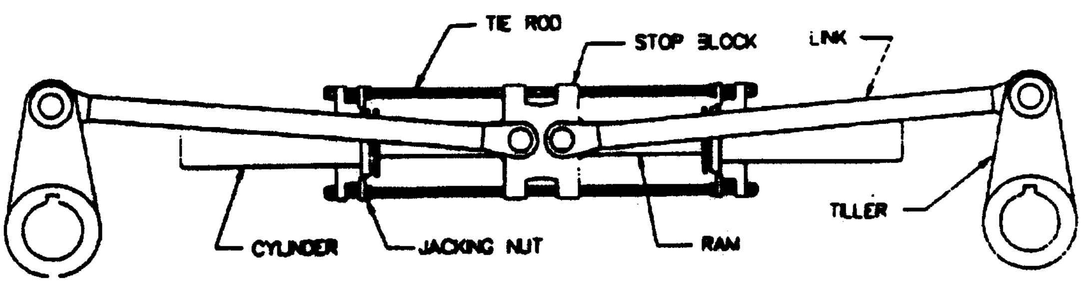


Figure 562-4-6 Link and Tiller Assembly

562-4.2.2.1 Tiller. The tiller is a two-piece casting, bolted together and keyed to the rudder stock. The tiller has an upper and lower yoke with a vertical through hole. The eye of a link slides between the upper and lower yokes and a pin holds the link in place.

562-4.2.2.2 Mechanical Rudder Angle Indicator. The mechanical rudder angle indicator consists of a scale and a pointer. As the ram moves, the scale moves relative to the pointer. Graduations on the scale show the exact position of the rudders at all times. The mechanical rudder angle indicator is used during emergency steering operations and to calibrate the remote rudder angle indicators located throughout the ship.

562-4.2.2.3 Ram. The ram has two vertical holes drilled through it for ram pins which connect each link to the top of the ram. The center of the ram is rectangular. A stop block mounted to the front of the ram houses a bushing that rides along the tie rod. The stop block and tie rod function the same as they do for the Rapson-slide.

562-4.2.2.4 Links. The steering system has two links. The links are attached above the ram and in the center of the tiller arms by pins. The elevations of the ram and tiller ensure that the links are horizontal, preventing the pins from binding during operation.

562-4.2.2.5 Cylinders. Two opposing cylinders, aligned perpendicular to the rudder stocks, operate a common ram. The cylinders are connected by tie rods. Stops limit the travel of the ram and the rotation of the rudders.

V-packings seal the ends of the cylinders and maintain a film of oil on the ram. Bronze bushings within the cylinders support the ram. These bushings, however, do not see significant side loads as on the Rapson-slide systems.

562-4.2.3 ROTARY (VANE). The rotary (vane) actuator (Figure 562-4-7) is used in steering systems when the space near the rudder stock is limited. A cylindrical housing fits over the rudder stock so that the rudder stock actually becomes part of the actuator. Stationary barriers called stators are attached to the inside wall of the housing. A seal, attached to the inside edge of the stator, maintains contact with the rudder stock as it turns. A vane with seals along three edges is mounted to the rudder stock. The seals ride along the upper and lower surfaces and inner wall of the housing. The stators and movable vanes divide the actuator into compartments. Fluid from the hydraulic system is pumped into one of the compartments. The pressure that develops in the chamber exerts a force against the vane causing the vane to move and turn the rudder. The actuator provides constant torque regardless of the rudder angle. The rudder is held in position when the fluid is locked-in by the directional control valve. The vane seal must allow a slight amount of leakage to prevent the seal from running dry along the inside walls of the housing. The corners of the seals tend to wear, increasing the amount of leakage within the actuator. These tip seals are the only barriers between the high and low pressure sides of the main hydraulic loop in the actuator. For this reason, the vane tip seals are sensitive to routine, high pressure tests. The leakage can affect positioning accuracy and load holding ability. Maintenance accessibility is a major disadvantage of the vane actuator. Most actuators are too large to disassemble onboard ship. To replace the vane seal, a hole must be cut through the hull to remove the actuator. Although maintenance is a major disadvantage, the compactness of the vane actuator can make it the only viable option when space is limited. LST 1179 class ships use this type of rudder actuator. (Note: For simplicity, the text throughout this chapter refers to cylinders, rather than cylinders and vane actuator chambers, when discussing the operation of the actuators.)

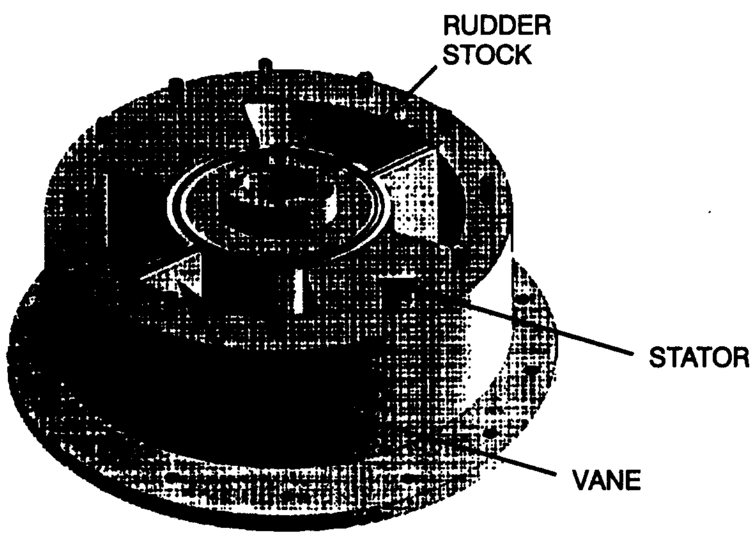


Figure 562-4-7 Rotary (Vane) Actuator

562-4.2.4 CLEVIS-MOUNTED CYLINDERS. The clevis-mounted cylinder arrangement (Figure 562-4-8) is used on smaller ships with steering systems that do not require high torque. The cylinders have a piston and rod rather than a ram. Cylinder rods pinned to the yoke on each side of the rudder stock operate the tiller. The cylinder body is mounted on a clevis. The clevis mount and tiller pin compensate for the arc-shaped movement of the tiller. Force can be applied through both cylinders during the extension and retraction strokes. To turn the rudder, one cylinder retracts while the other extends. The retraction stroke does not produce as much force as the extension stroke because the piston rod reduces the effective piston area. Therefore, the load imparted to the tiller is unbalanced and is supported by the stock bearings. Flexible hoses, which adapt to the cylinder motion, are used to connect the hydraulic system to the cylinders. Stops limit the travel of the tiller and prevent the pistons from bottoming on the cylinders.

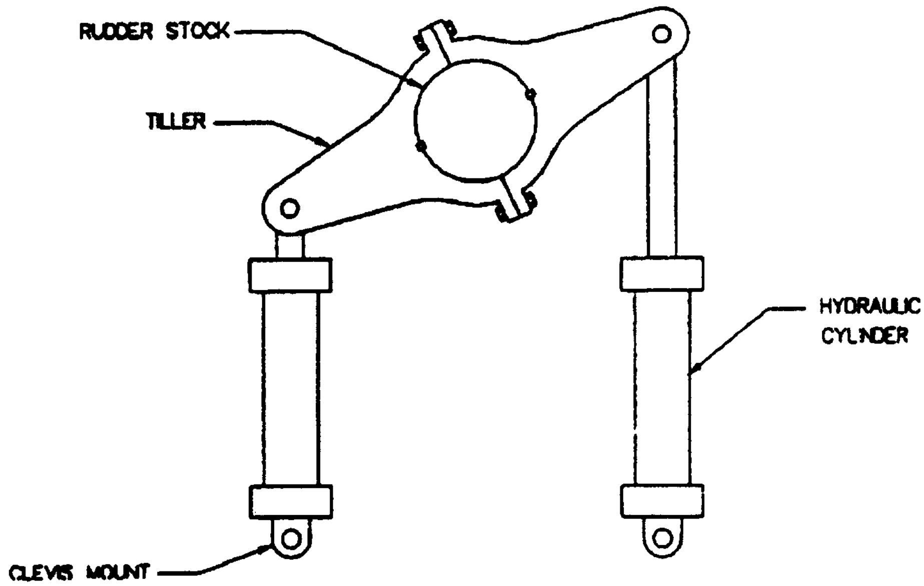


Figure 562-4-8 Clevis-mounted Cylinder Arrangement

562-4.3 ELECTRIC MOTORS

562-4.3.1 DESCRIPTION. The electric motors are 440-Vac, 3-phase, squirrel cage induction motors. Each motor drives the main pump and the replenishing pump. The direction of shaft rotation affects the direction of fluid flow to the cylinders. The motor is joined to the pump through a flexible coupling that compensates for minor misalignments between the motor shaft and the pump shaft. The flexible coupling allows for pump removal without removing the motor. **NSTM Chapter 300, Electric Plant-General** provides more information on electric motors.

562-4.3.2 LOW VOLTAGE RELEASE/LOW VOLTAGE PROTECTION. A motor controller controls the power to the motor. The motor is protected by low voltage release (LVR) and low voltage protection (LVP) acting through the motor controller. LVR is always applied to the active power unit. LVP is always applied to the standby power unit. LVR/LVP prevents damage to the motor from overheating caused by low voltage. In the event of a reduction or loss of voltage, LVR interrupts power to the main circuit. When control voltage returns to a specified level following a voltage drop, LVR reestablishes power to the main circuit (as long as the steering control stations selector switch remain in the LOCAL or REMOTE positions). LVP also works through the motor controller. In the event of a reduction or loss of voltage, LVP interrupts power to the main circuit and prevents the reestablishment of power until the supply voltage returns to normal and the operator restarts the motor. The difference between LVR and LVP is that LVR reestablishes power to the active or on-line power unit. LVP prevents the automatic startup of the standby power unit when the power is restored.

562-4.4 MAIN PUMPS

562-4.4.1 DESCRIPTION. On the majority of ships, the main pumps are axial piston, variable displacement, bidirectional pumps. There are two power units dedicated to each rudder actuator. Some power units have multiple pumps. Each pump has two main lines which are ported to a directional control valve. The directional control valve, also called the distributor valve, connects the on-line pump to the actuator. The valve is designed so that only one pump will be connected to the actuator at a time. Within the pump, pistons move back and forth within bores that are drilled in a cylinder barrel. The end of the piston is captured in a shoe. The shoe is attached to a plate within the pump called a swashplate. The swashplate, pistons and cylinder barrel form the rotating group. The rotating group is driven by the electric motor and always rotates in the same direction. The angle of the swashplate is controlled by the steering control system. Positioning the swashplate away from zero angle (no flow) is called stroking the pump. Stroking and destroking the pump alters the position of the swashplate and pistons but not the cylinder barrel. Figure 562-4-9 shows three possible swashplate positions. When the swashplate is at zero angle, the rotating group is turning but no fluid is pumped. When the swashplate is positioned at an angle, fluid enters the bore as the piston retracts. As the piston is retracting, fluid enters the cylinder bore through 180 degrees of rotation. Through the next 180 degrees of rotation, the piston pushes the fluid out of the pump as it extends through its bore in the cylinder barrel. The swashplate can be positioned at any angle from zero to its maximum stroke to control the amount of fluid being pumped. Since it is bidirectional, the swashplate can also be positioned to the left or right of the neutral position to control the direction of flow as shown in Figure 562-4-9. Within the pump, hydraulic fluid lubricates the sliding surfaces and dissipates some of the heat generated by the pump. This fluid leakage drains out of the pump case into the supply tank and is replenished by a second, smaller pump called the auxiliary pump. Replenishing pressure provided by the auxiliary pump maintains a positive pressure on the main pump return line to prevent pump cavitation. To prevent damage to the pump, the pump case must be completely full of hydraulic fluid before and during operation. The main pump incorporates a number of individual valve components designed to automatically control, direct, and limit pressure build-up of the main pump and auxiliary pump output flows.

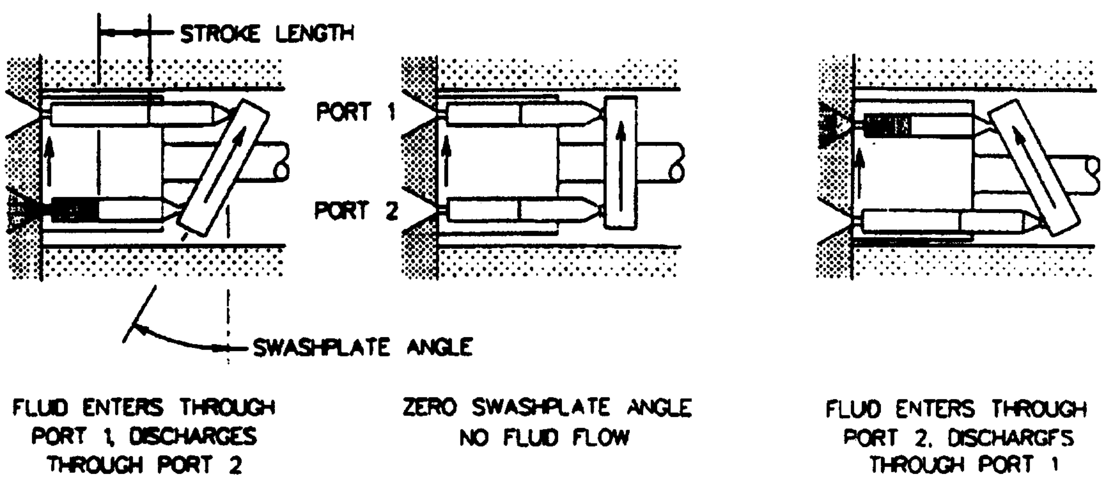


Figure 562-4-9 Main Pump Swashplate Angles

562-4.4.2 PUMP STROKE CONTROL. The pump stroke or swashplate angle is controlled by one of three ways:

a. Linkage-controlled servo valve. The linkage-controlled servo valve is mounted on the pump. The differential controls the position and movement of the linkage. In turn, the linkage moves the servo valve in proportion to the output of the differential. The servo valve directs fluid to the stroking pistons inside the pump. The stroking pistons position the swashplate to the correct angle, controlling the output of the main pump.

b. Electrohydraulic servo valve. The electrohydraulic servo valve is controlled by torque motors. The desired position of the swashplate is determined electronically. The torque motors direct fluid within the servo valve to position a valve spool. The valve spool directs flow from the auxiliary pump to a swashplate actuator in the main pump. The actuator positions the swashplate to obtain the correct pump output. The clearances and internal ports of the electrohydraulic servo valves are precisely machined and sensitive to contamination.

c. Direct linkage to the swashplate. Some pumps have a mechanical linkage connected directly to the pump swashplate. The linkage is moved by the output of the differential.

562-4.4.3 PRESSURE PROTECTION. All steering systems are equipped with some type of pressure protection to prevent unsafe pressures from building-up in the system. Pressure protection can be in the form of relief valves, horsepower limiters, or pressure compensators. All steering systems have relief valves. However, many systems have relief valves with either a horsepower limiter or a pressure compensator in the main pump.

562-4.4.3.1 Relief Valves. Relief valves protect the steering components from damage that results from excessive pressures. Most relief valves consist of a poppet and a spring. The pressure in the system acts against the spring. When the pressure exceeds a preset level, the force from the pressure acting on the poppet overcomes the spring force and opens a passageway for the fluid. Once the passageway is opened, the pressure decreases and the spring closes the poppet on the passageway. Relief valves are usually set at 10 percent plus 50 lb/in^2 above the maximum normal operating pressure. Relief valves should be tested and set only by experienced shipyard personnel.

562-4.4.3.2 Horsepower Limiters. To minimize the size of electric motors needed on higher torque steering systems, some of the main pumps are equipped with a horsepower (HP) limiter. The horsepower limiter, also called a torque equalizer, is a secondary, pressure-operated, stroke control mechanism for the pump. During periods of peak pressure, the horsepower limiter decreases the stroke of the pump so that the motor power required is nominally held constant at a preset value. The design of the horsepower limiter varies between pump manufacturers, usually consisting of a spring-loaded piston in a hydraulic cylinder. A shuttle valve connects the cylinder of the HP limiter to the high pressure side of the ram. When oil pressure builds up in the system due to high rudder pressure, the oil pressure overcomes the force of the horsepower limiter spring and the piston begins to move. The piston, through a linkage which overrides the steering control mechanism, reduces the pump stroke by an amount proportional to the load and thus reduces the power required to turn the pump. This permits a reasonably small motor to pump a large volume of oil at low pressure for fast rudder rates, and still provide the high pressure, at a reduced speed, required for high rudder torque.

562-4.4.3.3 Pressure Compensators. Some steering systems use a pressure compensator circuit on the main pumps to prevent overpressurization in the system. As pressure increases beyond a preset value in the system, the compensator reduces the displacement of the pump. If an excessive load is applied, the compensator will take the pump off stroke but will maintain pressure in the system. Once the load begins to move, the pump goes back on stroke. When used with relief valves, the relief valve setting must be higher than the setting of the pressure compensator for the compensator to function properly.

562-4.5 AUXILIARY PUMPS

562-4.5.1 DESCRIPTION. Auxiliary pumps, also called servo or replenishing pumps, are fixed displacement type pumps. They produce a set fluid output. Some systems use two auxiliary pumps for each power unit. One pump is used to produce servo pressure. The second pump is used in the replenishing circuit. Other steering systems use one auxiliary pump for both the servo and replenishing functions. These pumps are often driven by the same electric motor as the main pump; however, some systems use a separate motor to drive the auxiliary pumps. These pumps perform three major functions:

a. Servo (control). The auxiliary pump provides fluid to the servo valves, the pump swashplate actuators, the distributor valves, the transfer valves, and the Rotary Hydraulic Power Units (RHPUs). Not all steering systems have these components. The continuous output of the pump and the servo circuit design ensures that servo pressure is maintained at these components.

b. Replenishment. The auxiliary pump pumps fluid from the supply tank through the replenishment circuit and returns the fluid to the supply tank. The pump maintains a positive pressure on the main pump return line to prevent cavitation of the main pump. The auxiliary pump replaces fluid in the main circuit that is used to lubricate the internal pump components. The pump also replaces any fluid lost because of leakage in the system. In most systems, the only hydraulic fluid filtration provided is through the replenishment circuit.

c. Cooling. The hydraulic fluid that lubricates the internal pump components exits the main pump through the pump case drain. If there is an oil cooler in the system, the oil will pass through the cooler. The fluid then returns to the supply tank.

562-4.6 DISTRIBUTOR VALVES

562-4.6.1 DESCRIPTION. Distributor valves, also called blocking or distribution valves, are directional control valves. They are located between the hydraulic power units and the rudder actuator. Distributor valves connect one of the two power units to the rudder actuator. These valves also provide a flow path for the standby pump. Distributor valves are operated in a number of different ways depending on the design of the steering system. On some systems these valves are operated by the main pump servo pressure and are controlled by solenoid-operated pilot valves. The distributor valve is sometimes connected to limit switches or other electrical device to provide LVR/LVP to the electric motors. The distributor valve holds the rudder in position in the event of loss of electric power, preventing any rudder movement from driving the pump.

562-4.7 TRANSFER VALVES

562-4.7.1 DESCRIPTION. Transfer valves control the LVR/LVP of the power unit and initiate the sequence of events that cause a transfer of HPUs from standby to on-line and on-line to standby. There are two methods used to operate transfer valves in steering systems:

a. Manual selector. A selector valve is shifted by a watch in after steering. There is no automatic power unit transfer available at the ship control console on the bridge. The manual selector is used on some LPD and AOR Class ships.

b. Automatic. The transfer valve operates the solenoid interlocking system that controls the LVR/LVP for the electric motors. The transfer valve can be operated from the bridge or manually in after steering by a lever on the distributor valve.

562-4.8 FLUID

562-4.8.1 DESCRIPTION. Steering systems use hydraulic fluid conforming to MIL-H-17672 (type 2135), **Hydraulic Fluid, Petroleum, Inhibited** . The cleanliness requirements for the fluid are discussed in Section 9. The operating temperature should be maintained at less than 160°F.

562-4.9 FILTERS

562-4.9.1 DESCRIPTION. Fluid filters conform to MIL-F-24402, **Filters (Hydraulic), Filter Elements (High Efficiency), and Filter Differential Pressure Indicators, General Specification For or MIL-F-24702, Filter Elements, Hydraulic, Disposable, General Specification For** . These filters are depth type filters. The filter assembly consists of a housing, disposable filter element, and a pressure drop indicator. There are several types of pressure drop indicators in use including mechanical pop-up indicators, pressure gauges, button indicators, and pointers. The filters also have bypass relief valve protection which allows fluid to bypass the filter when the pressure drop exceeds a preset value. When this happens, the filter element should be replaced immediately. The element is not cleanable. Further information on filters can be found in **NSTM Chapter 556, Hydraulic Equipment (Power Transmission and Control)** .

562-4.10 SEALS

562-4.10.1 DESCRIPTION. Seals and gaskets prevent or control the leakage of hydraulic fluid and prevent contaminants from entering the system. The seals used in the hydraulic equipment have been standardized to ensure the interchangeability of seals from different manufacturers and the logistical support of the equipment. **NSTM Chapter 078, Volume 1** is a comprehensive source of information on seals. The chapter presents an overview of how seals function, the current specifications and standards used for seals in shipboard systems, replacement part numbers for obsolete seals, information on seal identification and life of seals, and seal and packing installation techniques. More information on the selection, identification, and fluid compatibility of hydraulic system seals can be found in **NSTM Chapter 556** .

562-4.11 ACCUMULATORS

562-4.11.1 DESCRIPTION. Accumulators are pressure storage reservoirs in which hydraulic fluid is stored under pressure from the pump. Most steering systems use bladder type accumulators to supplement the replenishing pressure on the pump return line and provide additional fluid for the system, if there is fluid leakage (see Figure 562-4-10). A flexible bladder or pouch inside the accumulator is filled with nitrogen at a precharge pressure. The precharge pressure is usually 1/3 to 1/2 of the replenishing relief valve setting. When the precharge pressure is measured, the replenishing pressure and the main system pressure must be zero. On some steering systems, the main system pressure drops to zero immediately after the system is secured. On other systems, the main pressure drops to zero over a 24-hour time period. The remainder of the accumulator is filled with hydraulic fluid and connected to the auxiliary pump output line. This further compresses the gas when the system is operating. When there is a loss of pressure, some of the fluid in the accumulator discharges into the system.

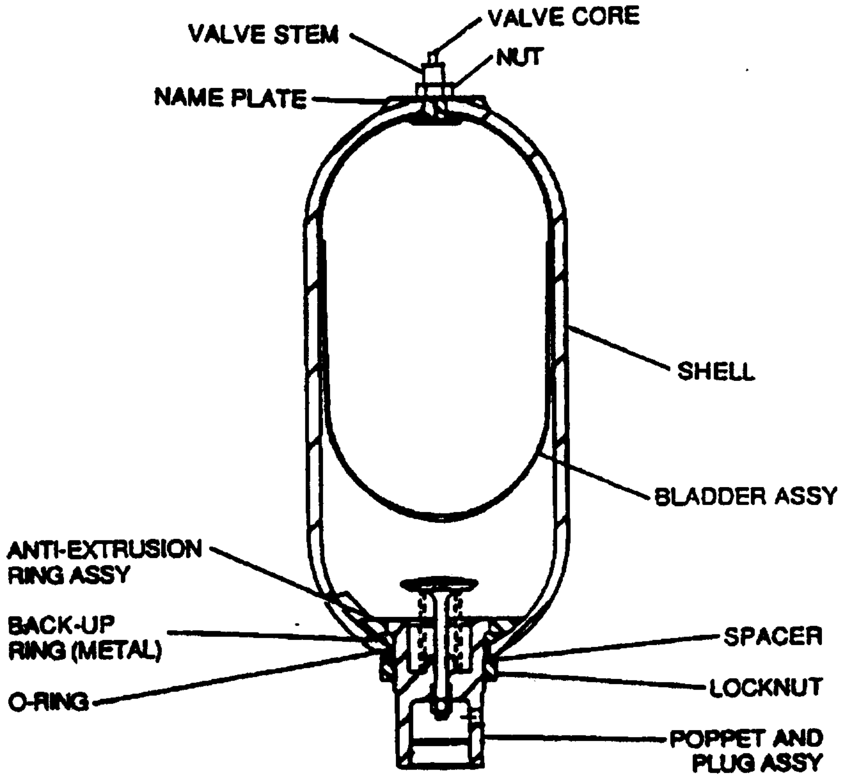


Figure 562-4-10 Typical Hydraulic Accumulator

562-4.12 OIL COOLERS

562-4.12.1 SHELL AND TUBE. Shell and tube type oil coolers are used to dissipate any excess heat generated during system operation. MIL-C-15730, **Coolers, Fluid, Naval Shipboard: Lubricating Oil, Hydraulic Oil, and Fresh Water** define requirements for shell and tube type coolers that meet shock resistance standards. Shell and tube heat exchangers consist of tubes that run the length of the shell (see Figure 562-4-11). The tubes terminate in tube sheets that hold the tubes in place and form a boundary between the cooling fluid and the hydraulic fluid. Baffles direct the flow of hydraulic fluid within the shell so that it is perpendicular to the tubes. The baffles also provide additional support for the tubes within the oil cooler shell. The water used to cool the hydraulic fluid is directed through the tubes. The hydraulic fluid flows around the outside of the tubes but within the shell. Chilled water or seawater cooling systems are used depending on what system is available on the ship. Chilled water systems provide a fairly constant temperature. Seawater system temperatures are affected by climate and outside water temperature. The oil cooler is located in the return line that is on the low pressure side of the circuit. Some hydraulic systems have a temperature-activated regulating valve installed upstream of the cooler on the water side to prevent excess cooling of the hydraulic fluid. When the system is initially started, the hydraulic fluid is cold and has a higher viscosity (thicker) than it does after the system has been operating for a time. The higher viscosity results in a higher fluid pressure that can be damaging to the oil cooler. Some coolers are protected by a bypass relief valve which directs the hydraulic fluid around the cooler until the pressure is within the design constraints of the cooler. The relief valve is installed upstream of the cooler and directs the return fluid to the supply tank.

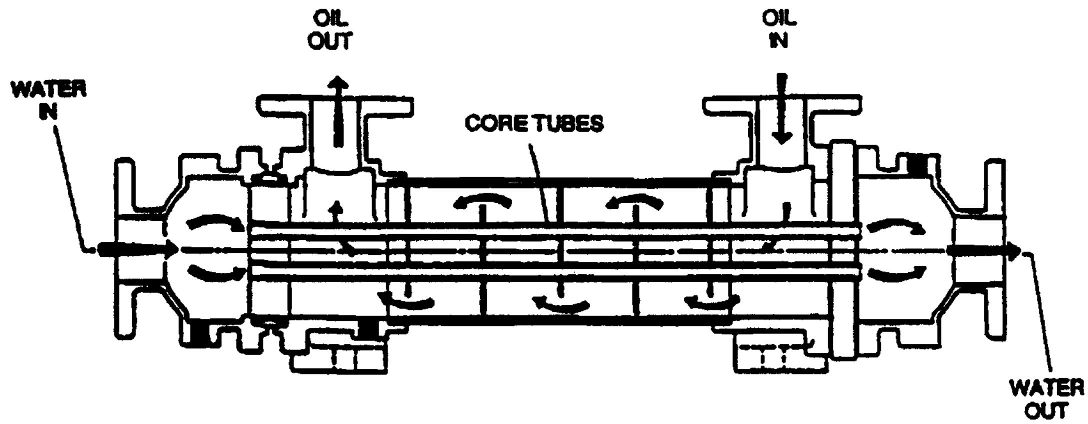


Figure 562-4-11 Shell and Tube Type Oil Cooler

562-4.12.2 AIR-OIL. Some ship classes such as the CVN 68 and CGN 36 use air-oil type coolers to remove heat from the hydraulic system. These coolers consist of a series of tubes with fins attached to the outside of the tubes. Hydraulic fluid passes through the tubes. A fan forces air flow around the tubes to help transfer the heat out of the fluid.

562-4.13 TANKS

562-4.13.1 SUPPLY TANKS. The primary function of the supply tank, also called the service tank, is to keep fluid in the system. The tank supplies fluid to the auxiliary pump and receives fluid from the system return line. The supply tank can also adjust to changes in the volume of fluid within the system such as when an accumulator discharges. The tanks help to remove air and contaminants from the fluid. The tanks are located close to the pump to minimize pressure drops in the connecting pipes. Most steering systems use a passive service tank design. Newer system designs such as the AOE 6 and DDG 51 use an active supply tank.

562-4.13.1.1 Passive Supply Tanks. Passive tanks are large tanks containing baffles (vertical tank dividers) that direct the flow of fluid within the tank. The baffles increase the amount of time the fluid is in the tank as it travels from the system return line to the pump suction line. In this way, particles can settle to the tank bottom and air can dissipate from the fluid. The surface area of the tank exposed to the atmosphere allows heat to dissipate.

562-4.13.1.2 Active Supply Tanks. Active supply tanks are smaller than passive tanks. The ones used in steering systems are fabricated from stainless steel and are not painted. The tank bottom has a conical shape with the outlet port at the bottom of the cone. The hydraulic fluid is filtered before it enters the tank and the conical shape prevents contaminants from settling at the bottom. Return fluid from the system is directed internally to produce a cyclonic flow in the tank. A fine mesh screen is installed in the tank to aid in the removal of air from the fluid. The air removal screen creates a pressure drop as the fluid passes through it. A bypass relief valve prevents screen collapse from any excessive pressure differential and subsequent damage to the pump. The cyclonic action causes the free air to collect at the center of the tank. A float valve passes any accumulated air to the space above the fluid in the connecting head tank.

562-4.13.2 HEAD TANKS. Head tanks are used to provide positive pressure on the auxiliary pump suction line at all times and to avoid air ingestion into the system. There are basically three head tank configurations found in steering systems.

a. Supply tank-mounted. Head tanks mounted to the top of passive-type supply tanks are made of stainless steel. This tank configuration keeps the supply tank flooded, preventing oil contamination caused by condensation-produced corrosion of the supply tank (see paragraph 562-9.2.2).

b. Structure-mounted, with supply tank. Head tanks used with active supply tanks are separate units, mounted to the overhead structure in the steering gear room. An overflow pipe connects the head tanks of the dual power units that connect to the same actuator. The overflow pipe allows fluid to pass between power units in the event of internal leakage to one power unit when the opposite power unit is operating. The overflow pipe also connects to the storage tank to direct fluid to the tank if the system is overfilled. Even though the head tanks are separate units, the connection they have with the storage tanks equalizes the pressure on all the power units. Figure 562-4-12 shows a typical supply tank - head tank configuration.

c. Structure-mounted, no supply tank. Some older ship tenders, such as the AE 21, have a gravity feed replenishment head tank in the overhead structure. This head tank connects to the main pump suction line through a shuttle valve. The function of the head tank is to maintain a pressure head on the main pump. These systems do not have replenishment pumps or supply tanks. Gravity feed replenishment head tanks are also used in emergency steering systems on CV 59 Class ships.

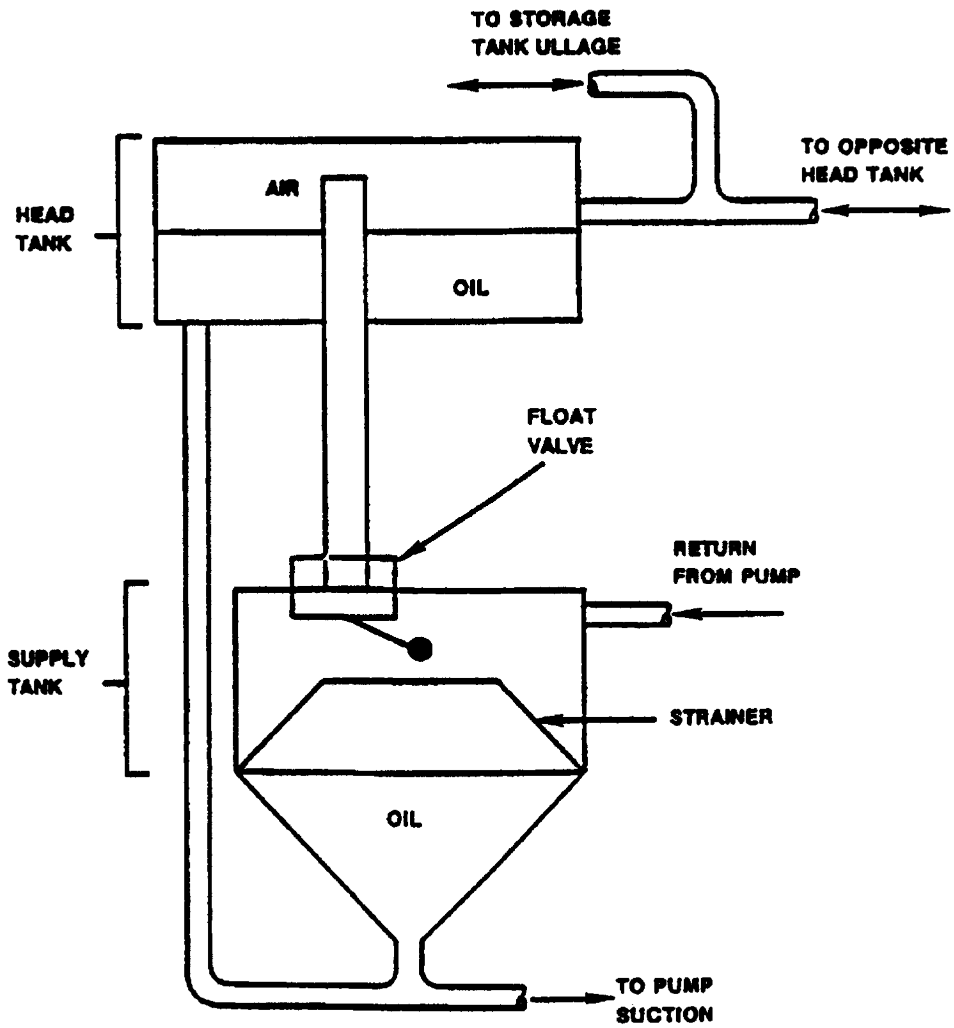


Figure 562-4-12 Supply Tank/Head Tank Arrangement

562-4.13.3 STORAGE TANKS. Storage tanks hold hydraulic fluid for use in emergency steering operations and to fill the main system, if needed. Storage tanks are also used to temporarily hold fluid from the system when the system is drained for maintenance. Generally, storage tanks are sized to hold 125 percent of the total system hydraulic fluid volume. Sight level indicators show the volume of fluid within the tank. Strainers at the fill connections help to prevent contaminants from entering the tank. Figure 562-4-13 shows a typical storage tank.

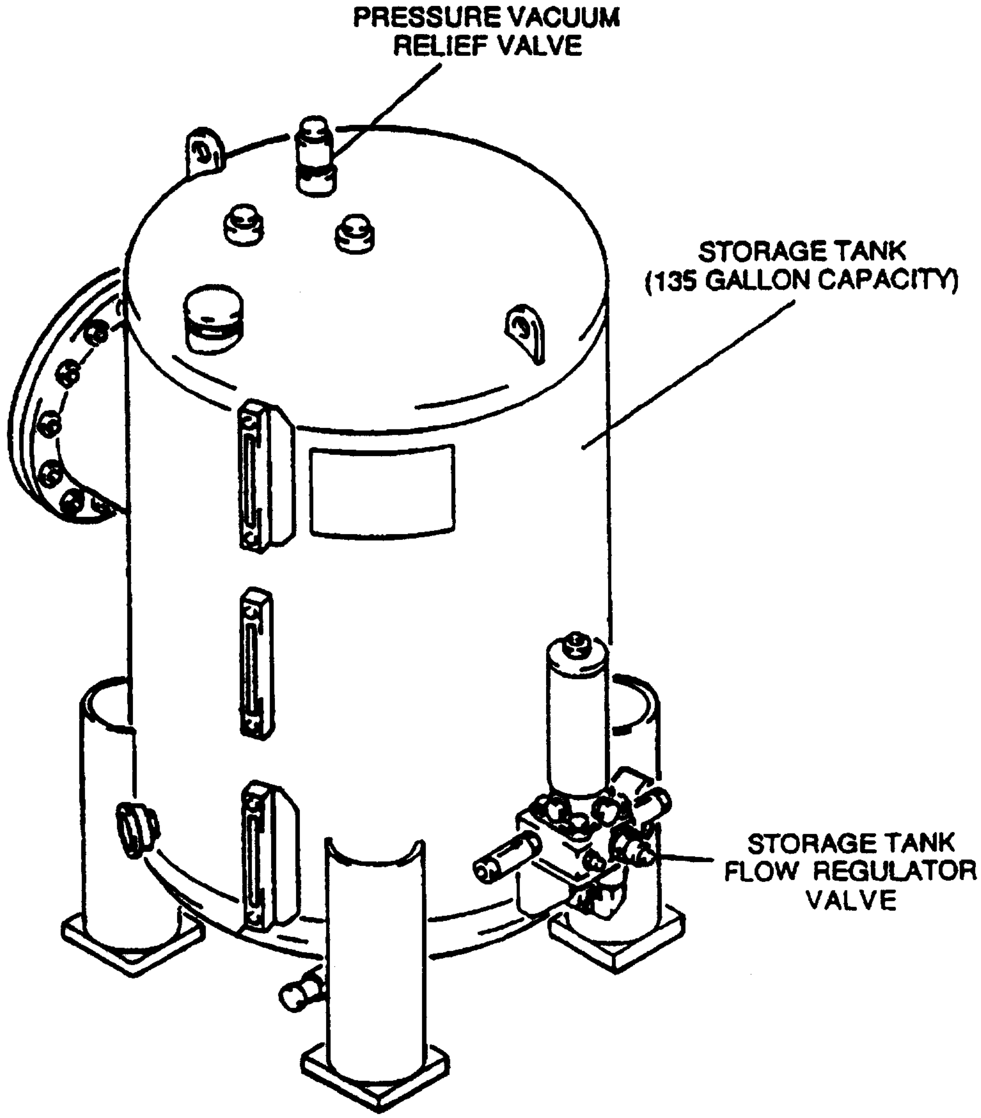


Figure 562-4-13 Typical Storage Tank

562-4.14 RESONATORS

562-4.14.1 DESCRIPTION. Some power units are equipped with sidebranch resonators tuned to the fundamental pump frequency (revolutions per second times number of pistons). The resonators reduce the main pump fluid pressure pulsation noise before the fluid enters the rudder actuator.

562-4.15 GAUGES AND SWITCHES

562-4.15.1 DESCRIPTION. Gauges and switches are installed at specific locations throughout the system to monitor temperature and pressure. The switches are connected to the control system to indicate a fault condition in the hydraulics. Some of the pressure gauges are designated CRITICAL and must be calibrated at specified intervals. A ship can upgrade a gauge to CRITICAL but can not downgrade a gauge to NON-CRITICAL.

562-4.16 MOUNTING

562-4.16.1 DESCRIPTION. The steering gear power unit which includes the motor and pump assembly is mounted on a common bedplate. The bedplate is sufficiently strong to limit or prevent any deflections between the pump and motor that may cause damage or misalignment. The mounting of the bedplate to the foundation may be either a rigid or a resilient mount.

562-4.16.2 RIGID MOUNT. Power units that are rigidly mounted have the bedplate fastened to the ship structure. When rigid mounting is used, piping is generally used to connect the power units to the rudder actuator.

562-4.16.3 RESILIENT MOUNT. Resilient mounts are pad type mounts made of a distributed isolation material (DIM). The DIM mounts attenuate noise and vibration but subject the components to deflections. DIM mounts with a mold date exceeding 10 years should not be used or should be replaced. When these mounts are used, additional free space is maintained around the power units so that the units will not hit any structure or other components during shock loading conditions. Hoses are used instead of piping to connect the hydraulic power units to the actuators. Since hoses are flexible and installed with additional length, they are able to compensate for the relative motion between the power units and the rudder actuator. The follow-up systems use slip joints, springs, or other means to pay-out or retract when there is relative motion between the units.

562-4.17 FLUID TRANSMISSION LINES

562-4.17.1 DESCRIPTION. Fluid transmission lines include the piping and hoses that connect the components of the hydraulic system. The piping and hoses are sized to limit the fluid velocity to 20 feet per second or less under all operating conditions. The lines leading to the cylinders are equipped with isolation valves so that the cylinders can be shut off from the rest of the hydraulic system. Systems with resiliently-mounted hydraulic power units have hose connections between the transfer valves and the cylinders and between the power units and overhead-mounted head tanks. The hoses have a five year service/shelf life and conform to MIL-H-24135, **Hose, Reinforced, Water and Oil Resistant and End Fittings, Reusable, for Flexible Hose Connections** . S6430-AE-TED-010, **Technical Directive for Flexible Piping Devices, Flexible Hose Assemblies** provides information on the selection, fabrication, test, inspection, and service life requirements for hose assemblies.

562-4.18 VENT AND TEST VALVES

562-4.18.1 DESCRIPTION. Some steering systems are equipped with vent and test valves in the hydraulic lines. These valves conform to MIL-V-24695, **Valve and Hose Assembly, Vent and Test, Hydraulic Services, General Specification For** . The valves serve as test points for measuring pressure, bleeding air, draining water, and collecting fluid samples for analysis. The vent and test valves seal by means of a spring-loaded check valve. A portable hose assembly with a probe on its end fitting depresses the check valve and opens the flow passage. A pressure gauge or valve can be attached to the other end of the hose for measuring pressure or removing fluid. The valves are located upstream and downstream of major components for pressure measurements. They can also be found at high points in the system for removing air and at low points for draining water.

SECTION 5.

STEERING CONTROLS

562-5.1 GENERAL

562-5.1.1 TYPES OF CONTROL SYSTEMS. There are three types of surface ship steering control systems: hand (electric), hydraulic telemotor, and digital.

562-5.2 HAND (ELECTRIC) CONTROL SYSTEMS

562-5.2.1 DESCRIPTION. Hand (electric) control systems used on Navy surface ship steering systems incorporate a differential control unit. Hand (electric) control systems are designed to operate the linkage-controlled servo valve on the main pump or the direct link to the swashplate. The major components of hand (electric) systems include helm wheels, switches and indicators, amplifiers, autopilots, Rotary Hydraulic Power Units (RHPUs), servo motor systems such as Rudder Command Servo Units (RCSUs), and the differentials. The type of components used in a control system vary among ships and ship classes. Not every piece of steering control equipment is discussed in this section. Some of the components discussed are not a part of every system. Specific information on a particular system can be found in its steering control system technical manual.

562-5.2.2 HELM WHEEL. The helm wheel, sometimes called the steering wheel or trick wheel, is part of a synchro transmitter assembly. The assembly includes the hand wheel and gearing that transmits the motion of the hand wheel to synchro transmitters. A friction brake or other damping system may be used to keep the hand wheel from creeping and maintain synchronism of the synchro transmitters and receivers. The wheel is mechanically connected to the Helm Order Indicator pointer so the helmsman can see the position of the wheel and the command angle. The helm wheel is geared to rotate through a wider range of degrees than the rudder or Helm Order Indicator.

562-5.2.3 SYNCHRO TRANSMITTERS AND RECEIVERS. The helm wheel on the ship control console drives synchro transmitters that are part of a synchro transmitter assembly. These synchro transmitters send signals to the synchro receivers in the steering gear room. A voltage imbalance between the synchros in the two locations is fed to a servo amplifier. The servo amplifier uses the voltage imbalance to control the component that turns the input shaft of the differential. The input shaft turns in proportion to the command angle. In this way, the command angle is mechanically input into the differential gearing by the input shaft position.

562-5.2.4 HELM ORDER/RUDDER ANGLE INDICATOR. The Helm Order/Rudder Angle Indicator has pointers superimposed on each other to display the helm position and the position of each rudder. The pointers are mounted with concentric shafting. The same scale, marked in degree increments for the maximum rudder travel left or right of zero, is used for both pointers.

562-5.2.5 AUTOPILOT. The autopilot allows the helmsman to enter a heading order for the ship. Electrical signals from the autopilot automatically control the rudder angle so that the ship maintains the heading without the need for steering with a helm wheel. The autopilot is operated from a control panel on the ship control console. The panel contains a heading order transmitter and adjustment knobs that limit the rudder swings and response according to the sea and weather conditions entered by the helmsman. The heading order transmitter has two synchros, a hand crank, and a numerical mechanical read-out. The heading order is entered by the hand crank and the heading order is displayed on the numerical read-out. When operating, the autopilot processes the heading order and the gyrocompass signal. The resulting signal is modified to match the hullform and other ship-specific parameters. The autopilot output signal replaces the signal produced by the helm wheel.

562-5.2.6 NONFOLLOW-UP CONTROLLER. The nonfollow-up controller (NFC) is a small control panel used to steer the ship from the bridge. The controller has one switch similar to a joystick control that can be turned to either LEFT RUDDER or RIGHT RUDDER to swing the rudder or turned to OFF to hold the rudder in position. The control signal functions as an on-off switch. When the controller switch is turned to the LEFT RUDDER position, the command moves left until the switch is turned to the OFF position. To center the rudder from this position, the switch must be turned to RIGHT RUDDER. The helmsman can watch the Helm Order

Synchro Position Indicator on the bridge (if available) to see the helm order. There is a lag between the time the control is switched to OFF and the time it takes the rudder to stop moving. The helmsman compensates for this lag during maneuvers.

562-5.2.7 STEERING MODE SELECTOR. The Steering Mode Selector is a rotary switch that allows the helmsman to select the method of steering the ship. Hand (electric), nonfollow-up, and automatic modes are available on most ships.

562-5.2.8 STEERING GEAR CONTROL AND STATUS PANEL. The steering indicator panel provides control switches and a positive visual indication to the helmsman of the operating status of the steering system and gyrocompasses. The panel contains START/RUN and STOP/READY pushbuttons for each of the power units. Indicator lights display the status of each power unit such as whether the unit is stopped, running in standby, or connected to the rudder actuator. Fault monitors are located throughout the system to detect faults so that immediate corrective action can be taken. The faults are identified on the steering alarm indicators panel near the helm at the ship control console. Machinery faults are isolated to the affected power unit. Main and auxiliary gyrocompass faults are indicated along with failures in the autopilot, failures in the port or starboard steering control power cables, problems in the transfer of power units from active to standby, and loss of the ship's heading reference signal from the main interior communications switchboard to the autopilot.

562-5.2.9 STEERING CABLES. Electrical cables carry steering control signals between remote steering stations and the steering gear room. Duplicate cables are provided and are separated between the port and starboard sides of the ship to increase the survivability of the system.

562-5.2.10 AMPLIFIERS. Steering control amplifiers develop the signal that is used for controlling the Rotary Hydraulic Power Unit (RHPU). The amplifiers convert the electrical signals from the helm synchro transmitter assembly into control signals that operate the input shaft of the differentials. The amplifier units consist of a rudder order data processor, rudder order computer, rudder servoamplifier, demodulators, and power supplies. The amplifier combines the rudder order signal with the present position of the RHPU shaft. It then produces an output that operates the solenoids of the RHPU control valves. The solenoids direct the hydraulic fluid within the RHPU so that the RHPU shaft is positioned in proportion to the rudder order signal. The amplifiers also contain autopilot circuitry which can process a heading order into signals that operate the RHPU solenoids in the automatic steering mode. The signals produced by the autopilot cause the rudder(s) to turn as needed to maintain the desired heading.

562-5.2.11 STEERING DISCONNECT UNITS. The Disconnect Unit controls the power to the control system. The unit is energized when the corresponding motor controller is energized. Disconnect Units have a manual on/off switch that connects or disconnects bridge control. It can be used to isolate the control system from the power units so that steering can be performed through the differential trick wheels. The units also have a remote/local switch. When set at remote and the motor controller is set at remote, the electric motor can be started and stopped at the bridge with the disconnect switch positioned at off. Signals to and from the RHPUs are routed through the Disconnect Unit.

562-5.2.12 SWITCHBOARDS. Steering control switchboards are located in the steering gear room and serve as an interface between the Ship Control Console or other remote steering stations, the Interior Communications System, and the Rudder Command Servo Units (RCSUs). The switchboard contains indicator lights for system status information, fuses, and rotary switches and pushbuttons for steering control functions. The switchboard is used to transfer control between steering stations and to secure remote control signals when operating with the differential trick wheels. The switchboard also functions as a distribution point for transmitting signals from the bridge to each of the RCSUs. Rudder angle information and alarm signals are transmitted through the switchboard. Indicator lights show which power units are operating and whether electrical power is available.

562-5.2.13 AFTER STEERING CONTROL UNIT. The After Steering Control Unit (ASCU) is a control panel located in the steering gear room. The ASCU provides an electrical means of steering control from the steering gear room without use of the trick wheels.

562-5.2.14 DIFFERENTIAL CONTROL UNIT. A differential control unit, or follow-up control box, is mounted adjacent to each power unit. The differential mechanism measures any difference between the helm angle and the rudder angle and strokes the pump swashplate to eliminate the difference. Since the pump is bidirectional, the differential controls the direction and rate of rudder movement. There are three shafts operating through the differential at any one time. The input shaft, follow-up shaft, and the output shaft of the differential rotate proportionally to the angle they are measuring or controlling. The rudder command angle can be input into the differential through the trick wheel on the differential or through an electrically-controlled actuator. These actuators can be either a Rotary Hydraulic Power Unit or a servo motor system depending on the system configuration. The second shaft is the rudder position feedback from the mechanical follow-up system. The third shaft is the output of the differential which connects to the pump stroking mechanism. The differential allows the helm to lead the rudder by the amount of the maximum angle from hard-over to hard-over without mechanical interference or jamming of the controls. In this way, the rudder seeks the position of the helm whenever the command angle is changed.

562-5.2.15 ROTARY HYDRAULIC POWER UNITS. The Rotary Hydraulic Power Unit (RHPU) contains a low inertia fluid motor that rotates the input shaft of the differential. A 4-way directional valve within the RHPU controls the direction of motor rotation. The directional valve is solenoid operated, receiving its control signals from the steering control switchboard or amplifiers. When the motor is positioned to obtain the correct rudder angle, hydraulic fluid flow from the auxiliary pump is directed away from the directional valve through a bypass valve. The bypass valve is also solenoid operated. The RHPU contains a control loop consisting of a synchro transmitter follow-up system. The synchro generates signals proportional to the RHPU shaft position. These signals are used by the control system to determine the direction and amount of rotation needed from the RHPU to position the rudder to the command angle. The signals also allow the control system to determine when the RHPU shaft is properly positioned.

562-5.2.16 SERVO MOTOR SYSTEMS. The primary function of servo motor systems is to translate the electrical signals from the remote steering stations into a mechanical rotation so that the steering commands can be input into the differential. During operation, signals from the synchro receivers in the steering gear room are compared to signals from the servo motor connected to the differential input shaft. If there is a difference between the two signals, an error signal is produced. The error signal causes the servo motor to turn so that its position is proportional to the command angle. Each servo motor system has its own feedback loop, usually consisting of a tachometer. The tachometer provides a stabilizing influence on the servo motor rotation.

562-5.2.16.1 Rudder Command Servo Units. The Rudder Command Servo Unit (RCSU) is a specific type of servo motor system. There is one RCSU for each differential. The RCSU consists of a control assembly, a drive assembly, and a cable assembly. To operate the rudder, the RCSU receives a synchro signal from the remote control system (bridge) for an ordered rudder movement. The RCSU control assembly operates a servo motor in its drive assembly so that the RCSU shaft moves to the proper position. The servo motor sets the cam of the steering gear mechanical differential so that the pump is stroked to achieve the desired rudder position. The RCSU has an internal control loop. As the servo motor moves, it drives the feedback control transformer and tachometer generator. The control transformers null the voltage to the servo motor as its shaft reaches the position corresponding to the ordered rudder position.

562-5.2.17 DIFFERENTIAL HELM WHEELS. Helm wheels, located in the steering gear room at the differentials, are used to steer when other modes of steering are not available. The helm wheels are manually operated and perform the function of the RHPU or servo unit. One port and one starboard helm wheel is required to operate two rudders. The other two helm wheels are in standby. Helm wheels are disengaged by a pin lockout device when not in use. Some designs use a two-position lever control box to engage and disengage the helm wheel. Remote steering control systems shall be deenergized at the switchboard when steering with differential helm wheels.

562-5.2.18 PORTABLE STEERING CONTROL UNITS. Portable Steering Control Units (PSCUs) allow the helmsman to steer in either the hand (electric) or automatic steering modes from either the port or the starboard bridge wings. PSCUs are installed on CG 47, DD 963, and DDG 993 class ships. The PSCU contains the switches and indicators necessary to enter helm order or heading commands and monitor the position of the rudder. The unit is intended for use in any situation where lateral visibility is important, such as while docking or refueling. The unit ties into the ship control console so that signals to and from the PSCU are routed through the bridge steering equipment. An alarm sounds should the unit inadvertently become disconnected without transferring steering control to the bridge.

562-5.3 DIGITAL CONTROL SYSTEMS

562-5.3.1 DESCRIPTION. The digital control systems used on Navy surface ship steering systems incorporate a digital controller and Standard Electronic Modules (SEMs) to control the position of the ship’s rudders. Digital control systems are designed to operate the electrohydraulic servo valve on the pump. Digital control systems provide a self-adaptive autopilot with performance features such as best heading and best fuel modes. The digital controller is equipped with built-in-test capability. It monitors the electronic communications within the control system and the fault sensors in the machinery. A control and maintenance panel in the steering gear room displays fault information to personnel without the need for tables or manuals. Digital systems have been designed to operate through a Data Multiplex System (DMS) which is a communications system which relays ship information. Since not all ships are equipped with DMS, the digital steering control system is adaptive to ships with or without DMS interfaces. The major units of digital control systems are the Bridge Steering Unit (BSU), the After Steering Unit (ASU), and the Local Control Units (LCUs). The BSU and the ASU each contain a Steering Power Control Panel, a Steering Mode Control Panel, an Automatic Steering Control Panel, a Helm Angle Indicator, an Emergency Override to Manual Panel, a Steering Wheel Assembly, and interface electronics for communications with other ship systems and for communications between the ASU and BSU. The digital controller and the Control and Maintentance Panel are housed in the ASU in the steering gear room. The LCUs provide an alternate means of steering from the steering gear room.

562-5.3.2 DIGITAL CONTROLLER. The digital controller controls the memory, input/output, and the applicable digital interfaces to control the steering system. The digital controller used on the DDG 51 is the AN/UYK-44 processor. Other systems may use commercial controllers. Unless the digital controller is bypassed, steering control signals are controlled and monitored through the digital controller.

562-5.3.3 STANDARD ELECTRONIC MODULES. Standard Electronic Modules (SEMs) are used in the control system. SEMs are electronic cards that have been standardized by the Navy to provide specific functional performance.

562-5.3.4 BUILT-IN-TEST. Built-In-Test (BIT) equipment provides the automatic test capability to detect, localize, and isolate faults within the steering system. Faults are defined as a degradation in performance due to detuning, maladjustment, misalignment, or failure of parts. BIT operates in the background of the prime steering control functions. It does not interfere with the operation of the prime control equipment. Its design allows the prime equipment to continue operating even if the BIT feature is non-operational.

562-5.3.4.1 When a fault is detected, indicator lights show the helmsman the criticality of the fault. The fault is also displayed on the Control and Maintenance Panel in the steering gear room. BIT isolates the fault to a group of SEMs to facilitate troubleshooting and module replacement.

562-5.3.5 HELM WHEEL. The helm wheel assembly has a helm angle indicator and rudder angle indicators. The wheel is mechanically attached to potentiometers and a synchro transmitter. The assembly generates an electrical signal proportional to the helm order. The signal is routed through the interface electronics and is processed by the digital controller. The helm wheel signals are also hardwired to the Local Control Units in the steering gear room to provide backup manual steering operation if the digital controller is not operating.

562-5.3.6 STEERING POWER CONTROL PANEL. The Steering Power Control Panel contains a set of switch/indicator pushbuttons that allow the helmsman to stop, start, and connect the hydraulic power unit (HPU) to the rudder actuator. Lights within the switches show the status of each HPU. The panel also contains a set of indicators for each HPU that shows whether the HPU is ready or not ready, when a fault condition exists in the HPU and the criticality of the fault. The fault indicators are also switches that allow the helmsman to acknowledge that the alarm has been recognized. The machinery faults are grouped into critical, major, and minor categories.

562-5.3.6.1 Critical faults include:

a. Low hydraulic fluid level in the head tank
b. High hydraulic fluid temperature in the main pump case drain piping
c. Electric motor overload
d. Loss of ac power

562-5.3.6.2 Major faults include:

a. Low hydraulic fluid level in the head tank
b. High fluid temperature in the supply tank
c. Low servo pressure
d. Servo control error
e. Low replenishment pressure
f. High motor temperature

562-5.3.6.3 Minor faults include:

a. Dirty fluid filter in the return line

b. Dirty fluid filter in the servo line

c. Loss of one set of electronics in the LCU

562-5.3.7 STEERING MODE CONTROL PANEL. The Steering Mode Control Panel allows the helmsman to select automatic, manual, or backup manual modes of steering and provides switch indicators for transferring steering control between the bridge and aft steering units. Indicators light up when a critical, major, or minor fault is detected in the steering control system. These indicators are combined with switches so that the helmsman acknowledges the fault by pressing the switch. The panel provides a switch/indicator for turning on and off the heading monitoring feature and sounding an alarm when the ship is moving off course.

562-5.3.8 AUTOMATIC STEERING CONTROL PANEL. The Automatic Steering Control Panel provides the switches, indicators and displays to control the autopilot and associated features. The autopilot is self-adaptive so that weather adjustments and rudder multiplier inputs are not needed. The helmsman enters a rudder limit setting to prevent any unwanted large rudder swings. A keypad allows the helmsman to enter the heading order. As the numbers are punched in, they are displayed. When the helmsman is ready, a left execute or right execute switch enters the display into the autopilot as the ordered heading. The autopilot allows immediate excursions to the left or right within the rudder limit setting. This feature temporarily overrides the autopilot. In addition to basic course keeping, the autopilot provides best fuel, intermediate, and best heading controls. The best fuel feature allows some deviation off course in order to minimize the ship's fuel consumption as much as possible. The best heading option will maintain the ordered heading as best as it can.

562-5.3.9 EMERGENCY OVERRIDE TO MANUAL. An Emergency Override to Manual pushbutton switch is provided at the bridge and aft steering units for emergency transfer of steering control modes to the backup manual mode. The switch overrides the digital controller and serves as a secondary method of transferring control between stations should a fault occur which prevents transfer using normal procedures.

562-5.3.10 LOCAL CONTROL UNITS. There is a Local Control Unit (LCU) for each hydraulic power unit. The LCU contains SEMs and the electronics necessary to convert analog signals to digital and digital signals to analog. The primary function of the LCU is to control the electrohydraulic servo valve on the pump. During normal operation, the LCU translates signals from the digital controller and the Rudder Angle Transmitter Unit (rudder position) into signals that operate the torque motors of the servo valve. The LCU is powered by the motor controller and supplies power to its associated Rudder Angle Transmitter Unit. Hand control potentiometers are provided on each LCU, providing additional rudder angle control locations. The location for entering helm orders (normal, bridge, aft, or one of the LCU's) can be selected through a Helm Order Source switch on each LCU. The LCU can be put into a test mode which puts the unit off-line and allows the digital controller to assess its operability. The operator can disable control of the LCU and its associated power unit by the digital controller through a switch on the LCU.

562-5.3.11 CONTROL AND MAINTENANCE PANEL. The Control and Maintenance Panel is located in the Aft Steering Unit. The panel is controlled by the digital controller and BIT electronics. A fault indicator keeps track of faults that have been detected in the system. The fault information is displayed to maintenance personnel in a readable and understandable format to reduce troubleshooting time. The Control and Maintenance Panel also allows personnel to reset the digital controller.

562-5.4 HYDRAULIC TELEMOTORS

562-5.4.1 FUNCTION. A hydraulic telemotor is a device used to control the steering gear of the ship from the pilot house or control station. Telemotors are employed most often in conjunction with the electrical steering control systems of replenishment-type ships, as opposed to combatant-type ships.

562-5.4.2 DESCRIPTION. The hydraulic telemotor system consists of one or more transmitters located at a distant steering station(s) connected by piping to a receiver(s) located in the steering engine room. Each transmitter and receiver unit is arranged so that movement of the steering wheel forces oil through the system resulting in movement of the plungers in the receiver unit. The receiver plungers are connected to the pump control or the steam-valve operating mechanism of the steering engine. Most telemotor systems are designed to use a reversible, parallel piston rotary pump to deliver oil to the receiver. In this system the transmitter can continue to be turned, regardless of leakage, until the receiver reaches the end of its stroke. At the end of the stroke the oil pressure builds up until a relief valve opens and the oil is discharged to a built-in supply tank. To make up for leakage, replenishing oil is automatically drawn from this supply tank as required. No centering springs are installed on the receiver units of this system; therefore, no wheel effort is required to hold a given rudder angle. Synchro type indicators are used with this system to relay to the helmsman the angle called for at the telemotor receiver. The indicator transmitter is gear-driven from the telemotor receiver plunger and the indicator receiver unit is mounted in the steering console.

562-5.4.3 FILLING TELEMOTOR SYSTEMS. Specific filling and purging instructions for the telemotor systems should be obtained from applicable steering gear or telemotor manuals because these instructions vary depending on the type of unit and the specific installation. Care should be exercised to ensure that the replenishing tank for each type of system is kept at least 3/4 full of oil at all times. Telemotor systems use fluid conforming to MIL-H-17672 (type 2075-T-H), **Hydraulic Fluid, Petroleum, Inhibited** .

SECTION 6.
RUDDER POSITION FEEDBACK EQUIPMENT

562-6.1 TYPES OF EQUIPMENT

562-6.1.1 DESCRIPTION. Rudder position feedback systems provide the steering control system with a mechanical or electrical signal that is proportional to the actual rudder angle. Each system is connected to the rudder stock or rudder actuator and operates continuously. Rudder angle synchro transmitters provide rudder position feedback to the ship control console and to other remote locations throughout the ship.

562-6.2 MECHANICAL FEEDBACK SYSTEMS.

562-6.2.1 HELIX SCREW FEEDBACK SYSTEMS. The helix screw assembly consists of a helix screw and cam follower mechanism, sometimes called a helix nut. The cam follower rides along the helix screw and is attached to the crosshead of the ram or is retained by the upper pin plate and fixed to the ram pin. The linear motion of the ram causes the cam follower to move and rotate the helix screw. The groove in the helix screw is spaced so that the screw rotates in proportion to the rudder shaft, not the ram. Consequently, the current rudder position is mechanically transmitted to the differential follow-up shaft by gearboxes and linkages.

562-6.2.2 CABLE FOLLOW-UP SYSTEMS. There are different configurations of cable follow-up systems. The principle of operation is to use the cable to transmit the rotation and position of the rudder to a position and rotation of the follow-up shaft on the differential. The ends of the cable can be attached to the tiller or the actuator. The cable can be used in conjunction with a chain and sprocket assembly or can be wrapped around a drum so that the sprocket or drum turns in proportion to the rudder. When cable systems are used in steering systems with resiliently mounted power units, the cable system design must allow the cable to pay out and retract during shock conditions.

562-6.3 RUDDER ANGLE SYNCHRO TRANSMITTER.

562-6.3.1 DESCRIPTION. A rudder angle synchro transmitter, mechanically linked to the rudder stock, transmits the actual rudder position to stations throughout the ship. The output of these units are integrated into the Interior Communications System. These transmitters are independent of the mechanical follow-up system which provides a rudder position feedback signal to the steering gear differentials.

562-6.4 ELECTRICAL FEEDBACK SYSTEMS.

562-6.4.1 RUDDER ANGLE TRANSMITTER UNITS. Systems that use electrohydraulic servo valves depend on an electrical signal that is proportional to the rudder position to stroke the pump correctly. The Rudder Angle Transmitter Unit (RATU) is central to the operation of the feedback system. The RATU contains dual potentiometers and a synchro and is powered by its respective LCU. The RATU is driven by a mechanical linkage that moves with the rotation of the rudder stock. The signal generated is proportional to the rudder position and is fed back to the control system. The RATU provides the rudder position feedback information to the steering control system and other ship systems. One RATU is provided for each LCU, providing redundancy in the feedback system. A separate unit for transmitting the rudder angle to remote ship locations is not necessary. Electrical feedback systems are used on the AOE 6 and DDG 51 ship classes.

SECTION 7.

EMERGENCY EQUIPMENT

562-7.1 TYPES OF EQUIPMENT

562-7.1.1 DESCRIPTION. Emergency equipment includes electrically powered pumps, hand pumps, chain falls, and ratchet wrenches. The electrically powered pumps and the hand pumps provide rudder movement at lower rates than the main system. The chain falls and ratchet wrenches are intended only for maintaining a rudder position or moving the rudder one or two degrees while the ship is not moving. The emergency equipment does not provide the same capability as the main system because the units are smaller. Also, there are no mechanical feedback systems. The operators control the rudder based on their view of the mechanical rudder indicator mounted on the ram or rudder stock. Every steering system is equipped with at least two methods of controlling or positioning the rudder in the event of a main system failure. The type of emergency equipment and the configuration of the equipment varies among different ships or ship classes.

562-7.2 ELECTRICALLY POWERED PUMPS

562-7.2.1 GENERAL. Electrically powered emergency pumps are intended for emergency steering operations. These pumps are also used for filling and draining the steering hydraulic system on some ships. The pump provides a fixed displacement output. Some systems use a variable displacement pump with the pump swashplate angle set to provide only a fixed displacement output. The pump is driven by an electric motor and its power is controlled by its own motor controller. It provides steering capability at reduced rudder rates. The pump draws fluid from the storage tank. The pump output flows through manually-operated directional control valves. The valve settings determine what actuator will be operated and in what direction the actuator will move. The valve can hydraulically lock the rudder in position. Check valves within the actuator piping prevent the loss of rudder control during aiding or restoring rudder loads.

562-7.2.2 CHECKBALL PISTON PUMPS. Some emergency systems use a checkball piston pump design for the emergency pump. Spring-loaded checkball valves inside of the pump control the flow into and out of each piston chamber. The fluid from the storage tank flows into the bearing cavity of the pump where the shoe holds the piston. During its suction stroke, fluid enters ports in the piston and enters the piston chamber through an inlet checkball inside the piston. During compression, the inlet checkball seats and pressure in the piston chamber rises. The pressure rises as the piston extends through its chamber because of the swashplate angle and the rotation of the piston group about the driving shaft. The pressure rises until it exceeds the load pressure from the checkball spring. The outlet checkball then unseats. Fluid is then pumped across the check and out of the chamber. The outlet checkball valves prevent cavitation damage that can be caused by partially filled piston chambers. The valve does not unseat until fluid pressure is high enough to overcome the spring force of the valve. The piston checkvalves eliminate valve plates which can wear or score with contamination. With no valve plate to wear, checkball pumps have a high volumetric efficiency and are relatively insensitive to contamination.

562-7.2.3 REVERSIBLE, ELECTRIC MOTOR-DRIVEN PUMP. Some ships, such as the LHA 1 class, are equipped with a fixed displacement emergency pump that can operate in two directions. A charge pump prevents cavitation. The pump is operated by positioning the valving, then operating the electric motor that drives the pumps in the proper direction. The valve positioning and direction of motor rotation controls the direction of rudder rotation.

562-7.3 HAND PUMPS

562-7.3.1 DESCRIPTION. Hand operated pumps provide a means of filling and draining the system and provide limited rudder movement under emergency conditions such as when electrical power is not available. Directional control valves direct the flow of fluid to the actuator and to the appropriate cylinder. Hand pumps are fixed displacement pumps that require one or two crewman to rotate crankarms to pump the fluid into the cylinder. Check valves control the movement of the rudder when an aiding load is present on the rudder.

562-7.4 RATCHET WRENCHES

562-7.4.1 DESCRIPTION. Ratchet wrenches are provided for positioning the threaded jacking nuts on the cylinder tie rods. The jacking nuts can be butted against the stop blocks on the ram to restrain rudder movement or move the rudder one or two degrees. The wrenches should only be used when the ship is not moving or is going at extremely low speed.

562-7.5 CHAIN FALLS

562-7.5.1 DESCRIPTION. Chain falls are provided on some ships such as the LSTs and AEs to hold a rudder in position. Attachment points are located on the tiller and padeyes are mounted on the bulkhead. Chain falls are used to hold the rudder in position or rotate the rudder a small amount when the ship is not moving or is going at extremely low speed.

SECTION 8.

DESCRIPTION OF SYSTEM OPERATION

562-8.1 GENERAL

562-8.1.1 DESCRIPTION. During normal steering operations, the control system compares the rudder command angle with the actual rudder position. Any difference between the actual rudder angle and the command angle causes the control system to stroke the hydraulic pumps. The pumps direct hydraulic fluid to rudder actuators connected to the rudder stocks, controlling the direction of rudder travel and the actual rudder position. As the rudder turns, the follow-up system sends a signal proportional to the actual rudder position to the controls. When the rudder position equals the command angle, the control system takes the pump off stroke. The system continually adjusts to changes in either the command angle or changes in rudder position that result from external forces acting on the rudder. Figure 562-8-1 shows the interaction of the major system components.

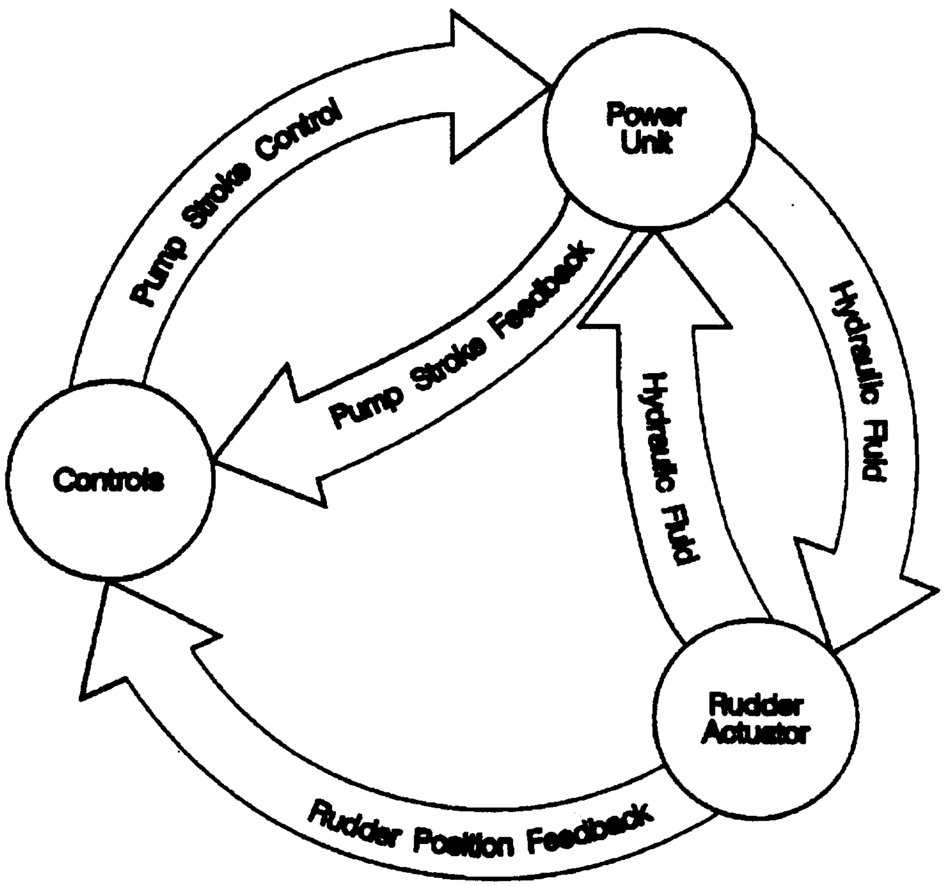


Figure 562-8-1 System Component Interaction

562-8.2 CONTROL SYSTEMS

562-8.2.1 DESCRIPTION. The primary function of the control system is to translate the rudder command into a signal that strokes and destrokes the pump. By stroking and destroking the pump swashplate to the correct angle and in the proper direction, the control system positions the rudder to the command angle. The system allows the helmsman to select which hydraulic power units are on-line, which cable is transmitting the signals, the operating mode, and other operating parameters. Control systems also perform a monitoring and alarm function. Status indicators on the control panels show the helmsman which power units are on-line, which are energized, and whether there are any faults detected by sensors within the system.

562-8.2.2 HAND (ELECTRIC) SYSTEMS. When the helmsman turns the helm wheel to a command angle, the synchro transmitters in the helm wheel assembly translate the position of the helm wheel into an electrical signal. The signal is transmitted to synchro receivers in the steering gear room. The control system determines the current position of the input shaft of the differential. The control system compares the input shaft position with the command angle to determine if there is an imbalance. When there is an imbalance between the two, the control system rotates the input shaft by energizing the component that operates the shaft. A feedback loop lets the system know when the input shaft actuator is approaching the correct position so that it can slow down and stop. The feedback also informs the control system when the shaft is positioned correctly. As the input shaft turns, the differential rotates the output shaft. This rotation moves a linkage connected either to the pump stroke control valve or directly to the pump swashplate. The pump directs fluid to the rudder actuator. Once the rudder actuator begins to move in the direction of the command angle, the mechanical feedback shaft on the follow-up systems begins to rotate. The follow-up shaft connects to the differential. When the position of the feedback shaft approaches the position of the input shaft, the differential begins to take the pump off stroke. The mechanical feedback operating through the differential checks that the position of the rudder stock is equal to the command angle.

562-8.2.3 DIGITAL SYSTEMS. When the helmsman turns the helm wheel to a command angle, the potentiometer assembly in the helm wheel assembly converts the helm wheel position into an electrical signal. This signal is compared to a signal from the Rudder Angle Transmitter Unit potentiometer to determine if the rudder angle equals the command angle. The control system then determines the pump stroke needed and the direction of hydraulic fluid flow to move the rudder into position. The system must energize the correct torque motor for a specific length of time. The torque motors of the electrohydraulic servo valve control the position of the valve spool that directs fluid to an actuator within the pump. The direction and amount of flow through the servo valve determines the position of the actuator. The actuator tilts the swashplate to a certain angle and in the direction determined by the control signals. The control system monitors the pump swashplate position so that it can correctly move the swashplate to turn the rudder to the command angle. When the rudder angle approaches the command angle, the control system energizes the servo valve torque motor so that the pump is taken off stroke. When the rudder angle equals the command angle, the servo valve torque motors are deenergized and the pump is set at zero stroke. A block diagram of digital control system operation is shown in Figure 562-8-2.

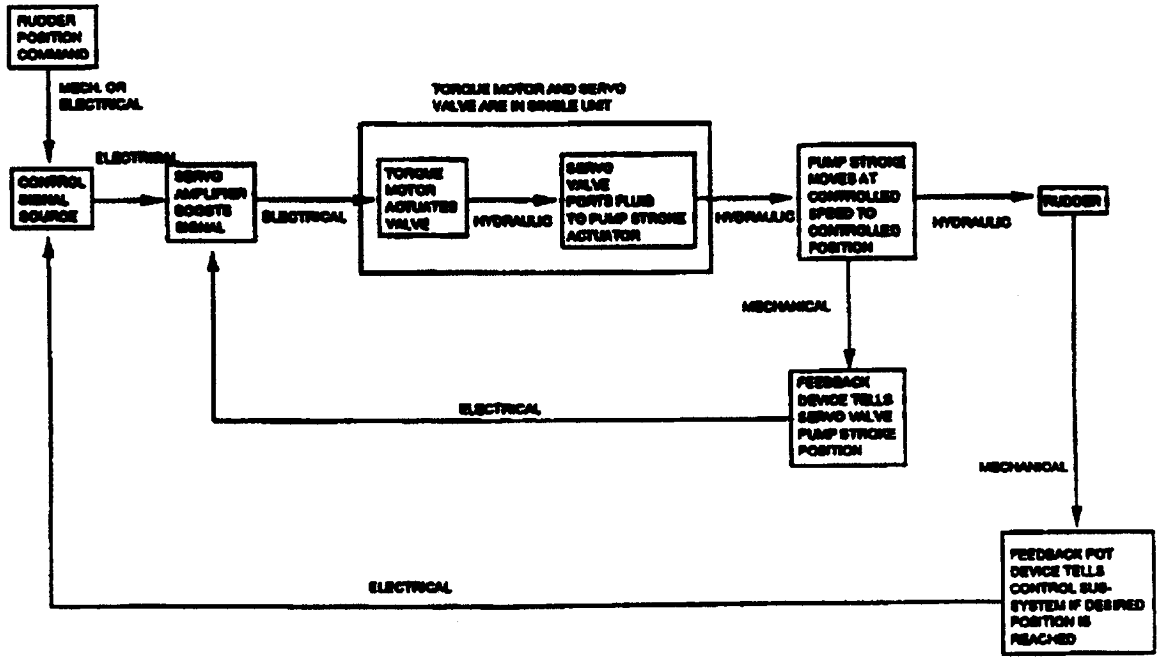


Figure 562-8-2 Block Diagram of Digital Control System Operation

562-8.2.4 CONTROL SYSTEM RESPONSE. The control system processes and compares signals continuously. However, there is some lag in the system because it takes time, even if it is a fraction of a second, to actually rotate the input shaft of the differential or move the spool of the servo valve. It takes additional time to position the pump swashplate which further slows the response of the rudder movement to the command angle. Each system may respond differently to command signals but still produce the same results.

562-8.3 HYDRAULIC SYSTEM

562-8.3.1 HYDRAULIC POWER UNITS. The hydraulic power units (HPUs) are driven by electric motors and controlled by the steering control system. Most HPUs have relief valves to prevent overpressurization, accumulators to maintain replenishment pressure and fluid levels, oil coolers to prevent overheating, and other components. During normal operation, several components operate or activate at the same time. When the on-line HPU is selected, the power unit electric motor starts and the transfer valve shifts to connect the pump to the actuator. The redundant HPU is placed on standby or is stopped. On some ships, the standby pump may go on and off stroke. The pump stroke can be determined if there is an external indicator on the pump. The distributor valve blocks the hydraulic fluid flow from the off-line unit to the actuator. At the time of the transfer, low voltage release (LVR) protection is placed on the active electric motor and low voltage protection (LVP) is placed on the standby unit. The control system adjusts the angle of the pump swashplate. Fluid from one side of the actuator is pumped into the other side of the actuator, causing the rudder to turn. During the pumping action, some fluid is needed to lubricate the inside components of the pump. The fluid used for lubrication of the pump flows into the case drain where it is routed through the oil cooler and into the supply tank. The auxiliary pump replaces the fluid lost to leakage and pump lubrication with fluid from the supply tank, maintaining positive pressure on the main pump suction line. The pumping action forces fluid into the cylinder resulting in a pressure increase. The pressure creates a force on the end of the ram. The force acting on the ram is converted to a torque on the rudder stock because of the configuration of the actuator.

562-8.3.2 MAIN PRESSURE. The pressure in the main system varies according to the angle of the rudder and whether it is moving. Most systems are designed so that the pressure needed for operation under full power steering conditions is less than 2350 lb/in^2 . However, the maximum operating pressure varies from ship to ship and can reach 2600 lb/in^2 . Full power steering conditions exist when the ship is going at full speed and the rudder is being turned hard-over to hard-over. If the pressure in the cylinder becomes higher than a preset pressure and the main pump is equipped with a horsepower limiter, the horsepower limiter on the pump automatically decreases the pump stroke. The decreased pump stroke slows the rate of rudder travel. Consequently, the horsepower limiter reduces the hydraulic power (a function of pressure and flow rate) needed from the steering system under peak loading conditions. Under most steering conditions, the rudder only turns 10 to 15 degrees so that the pressure required in the system is much less.

562-8.3.3 SERVO PRESSURE. The servo pressure is fairly constant and is set by the manufacturer. Depending on the system design, the pressure is usually between 150 and 700 lb/in^2 .

562-8.3.4 REPLENISHMENT PRESSURE. The replenishment pressure is usually 80 to 200 lb/in^2 .

562-8.3.5 HEAT GENERATION. Heat is generated when the system is operating. The heat is transmitted throughout the system by the hydraulic fluid. Oil coolers help to control the temperature of the fluid. When the temperature becomes excessive, the hydraulic fluid loses some of its ability to properly lubricate the moving parts of the system. For this reason, high fluid temperatures can lead to unnecessary wear on the components and degraded performance. An off-line pump running idle can be a major source of heat because energy is put into the system with no useful work being done by the pump. The energy converts to heat. If the fluid temperature reaches 70°F above ambient after operating in standby for four consecutive hours, heat generation can be considered a problem for the particular system. For this reason, the off-line pump should be stopped, rather than left in standby, during normal steering operation. Sensors within the hydraulic system activate an alarm at the steering stations when the fluid temperature exceeds a predetermined value, usually 160 to 175°F. Not all systems are equipped with high temperature alarms. The alarm indicates a need to transfer hydraulic power units to maintain steering and investigate the cause of the high fluid temperature.

562-8.3.6 RUDDER ACTUATORS. Rudder actuators require proper lubrication and alignment to operate trouble-free. The V-ring packings maintain a protective film of hydraulic fluid on the ram. Grease fittings are provided on the sliding blocks and stop blocks for lubricating the moving surfaces of the actuator that are not easily accessible. The ram is supported by bronze bushings within the cylinders. Over time the bushings wear, leaving bronze particle sediment in the bottom of the cylinders. The sediment is not harmful unless it becomes entrained in the fluid that circulates through the pump. Actuator alignment is particularly important in the Rapson-slide actuator (see paragraph 562-4.2). The large forces acting on the actuators during steering operations can cause uneven wear on the components if the alignment of the cylinders and the ram pin assembly is not exact. Just as the bushings wear, the sliding blocks can also wear. Misalignment or improper tolerances can result in a condition known as ram roll. Misalignment of the cylinders can also result in the loosening of the fitted foundation fasteners or vertical loads on the sliding blocks.

562-8.3.6.1 Ram Roll. Ram roll is a condition where the ram rotates about its longitudinal axis as the gear is moving the rudder. Wear of the components, misalignment or improper tolerances in the actuator assembly can contribute to ram roll. The alignment of the ram assembly components can also contribute to ram roll. Since the sliding block acts as a bearing between the tiller and the ram pin, the location and perpendicularity of the ram pin hole and the squareness of the edges and outside surfaces are important to the proper functioning of the

Rapson-slide. Ram roll is a concern when unnecessary loads are placed on the tie rod so that the tie rod bushing becomes worn. If this occurs, the sliding blocks should be rotated, switched, or replaced to eliminate the ram roll.

SECTION 9.
OPERATING PROCEDURES

562-9.1 GENERAL

562-9.1.1 SCOPE. This section provides a brief overview of the capabilities of the the different steering modes and describes recommended procedures for steering when a fault or casualty condition occurs.

562-9.2 STEERING STATIONS

562-9.2.1 LOCATIONS. Depending on ship requirements and the system configuration, there may be several locations available for controlling the steering system. At a minimum, the steering system can be operated at the bridge ship control console and at the after steering control station. Some systems have Portable Steering Control Units which allow steering from the bridge wings.

562-9.2.2 CONTROL TRANSFER. There are specific procedures for transferring control between steering stations for each type of system; however, all procedures include some important steps. The rudders and helm wheels of both stations affected by the transfer should be at zero degrees. This prevents a rapid rudder swing if one helm wheel is set at a different command angle. Both stations shall be manned for the transfer to be implemented. Finally, personnel should maintain communication between the two stations during the transfer so that potential problems can be averted.

562-9.3 OPERATING MODES

562-9.3.1 HAND (ELECTRIC) SYSTEMS. Hand (electric) steering systems have several operating modes available. However, not all modes are available on every ship.

562-9.3.1.1 Automatic. The automatic mode, also called the autopilot mode, engages the autopilot equipment to maintain a heading without the need for the helmsman to adjust the command angle. The helmsman enters a heading order and adjustments for different conditions such as wind and sea states, maximum rudder angles, and displacement. There are differences in the equipment and operation of the autopilot among the different autopilot manufacturers.

562-9.3.1.2 Hand (Electric). The hand (electric) mode uses electric signals generated by the remote helm wheel assembly or by a remote electrical control box in the after steering gear room, such as the After Steering Control Units on the DD 963 and CG 47 Classes, to enter the rudder angle command.

562-9.3.1.3 Nonfollow-up. The nonfollow-up mode uses a type of joystick control to turn the rudder to the left or right. In this mode, the steering system does not position the rudder to an ordered angle. If a helm order synchro position indicator is available on the bridge, the helmsman can watch the indicator to see the helm order. If the indicator is not available, the helmsman compensates for a lag between the time the control is switched to off and the time it takes for the rudder to stop moving. The mechanical follow-up components that connect the rudder actuator to the differential are used in this mode to null the pump stroke. This mode is used when the other remote steering operating modes normally available on the bridge have failed.

562-9.3.1.4 Local (Trick Wheel). The trick wheels on the differentials can be used to enter a command angle when other remote systems have failed. When steering from the differential trick wheel, the control system must be disconnected. If there are two sets of power units that are independently operated, each set has its own trick wheel operator. The command angle entered at one trick wheel is not automatically transferred to the other independently operated unit.

562-9.3.2 DIGITAL SYSTEMS. Digital steering systems have several operating modes.

562-9.3.2.1 Automatic. Digital systems have a self-adaptive autopilot that controls the steering through the digital controller. The helmsman sets the rudder limits and the heading order. The system automatically steers the ship. Best heading, intermediate, and best fuel performance mode options are available in this mode.

562-9.3.2.2 Manual. The manual mode allows the helmsman to steer the ship with the helm wheel. The signals are processed through digital controller.

562-9.3.2.3 Backup Manual. The backup manual mode allows the helmsman to steer the ship with the helm wheel. The signals are transmitted directly to the Local Control Units, bypassing the digital controller.

562-9.3.2.4 Local Control Units. The Local Control Units in the steering gear room can be used to enter a command angle when other remote systems have failed.

562-9.4 HYDRAULIC POWER UNITS

562-9.4.1 GENERAL. At the controlling station, the helmsman selects the steering mode and operates according to the operating orders for the particular ship. Status indicators on the steering control panels tell the helmsman what hydraulic power units are energized and what units are on-line. If installed, fault indicators illuminate when there are any faults detected within the system. The switches on the steering control panels provide the means of controlling the steering gear equipment. The on-line/off-line status of each power unit should be switched at 24-hour intervals. Both hydraulic power units should be run simultaneously only for the time necessary to check out and warm-up the system. Some systems will generate excessive heat that is detrimental to the pump if the standby unit runs idle for any length of time. Prior to switching units, the synchros of both units should be energized and operating. If both synchros are not operating prior to the transfer and the rudder is at an angle, there will be a large error between the helm and the rudder at the time of the transfer. During underway replenishment or when maneuvering in confined areas, all synchros should be operating. If excessive heat generation is not a problem, both power units can be energized. However, if heat is a problem, operating both sets of synchros allows the helmsman to start the standby unit and transfer control immediately in the event of a casualty. The standby unit will not be harmed if it operates the rudder without warm-up.

562-9.5 FAULT CONDITIONS

562-9.5.1 GENERAL. In the event of a fault, a sensor in the system activates an alarm through an indicator light or a combination of indicator light and audible alarm. All fault conditions require action to locate and correct the problem before it becomes a casualty condition. Because of the redundancy in the system, the first action is to transfer control to the alternate power unit and investigate the problem. If the fault occurs in the alternate unit, both units should be stopped if it is safe to do so.

562-9.6 STEERING CASUALTY

562-9.6.1 DESCRIPTION. A steering casualty occurs when any of the following loss of control situations or conditions exist:

a. Any or all of the Rudder Angle Indicators no longer follow the motion of the helm.

b. The rudders do not respond to the helm of the controlling station.

c. The low fluid level or high temperature warning lights indicate a fault condition on hand (electric) systems that have these indicator lights installed, or a critical fault occurs on a digital system.

d. The status indicators for the on-line power units do not show that a power unit is operating.

562-9.6.2 REGAINING CONTROL. In the event of a steering casualty, the alternate unit should be brought on-line. If possible and operating requirements permit, begin troubleshooting before the transfer is attempted. If all synchros have been operating, the power unit transfer will not result in unwanted motion of the differential. If steering control is not regained through the alternate unit, the following steps should be followed one-at-a-time until control of the system is regained:

1. Determine if one rudder can be controlled from the bridge and maintain control of that rudder at the bridge. Center the inoperative rudder locally and steer out of trouble.
2. Transfer control to the after steering station.
3. If only one rudder is available, place the inoperative rudder amidship and steer with the good rudder.
4. Man the emergency steering stations, place the rudders amidship, and steer by differential engine power.
5. Bring the ship dead in the water, manually jack the rudders to amidship, and steer by differential engine power.

In the event of a steering casualty on a single-rudder ship, the alternatives available include switching to a lower mode of steering and switching to the alternate power unit.

562-9.7 EMERGENCY SYSTEM OPERATING PROCEDURES

562-9.7.1 GENERAL. The emergency system is used when there is a failure or fault condition in the main system that prevents the main system from operating. The main hydraulic systems and the control system of the affected rudder must be disconnected or isolated. Specific procedures for connecting the emergency pumps are provided in the applicable system technical manuals. When electrically powered pumps or handpumps are used, the positions of the emergency system directional control valves determine the rudder actuator that will be operated and the direction of ram movement. The valves are clearly marked. There is no mechanical feedback system to adjust the pump stroke because the pump has a fixed displacement. The emergency system operators must observe the mechanical rudder indicator to see the rudder position.

SECTION 10.
MAINTENANCE AND TESTING

562-10.1 GENERAL

562-10.1.1 MAINTENANCE REQUIREMENTS. Maintenance activities for steering systems include preventive and corrective maintenance. Preventive maintenance is performed to keep the system in good operating condition and to minimize the risk of having an operational failure. Corrective maintenance is the troubleshooting and repair work done to correct a problem with the system. Not all steering systems have the same components. Consequently, the maintenance procedures are not identical for all the systems in use. Each steering system has a formal preventive maintenance plan which is part of the Planned Maintenance System (PMS). The specific maintenance procedures and scheduling requirements are outlined in the Maintenance Requirements Cards (MRC's). Recommended maintenance requirements are also found in the technical manuals for the system. These requirements may not be identical to those in the MRC's. The MRC's take precedence over the technical manuals. This section of the NSTM provides an overview of recommended maintenance practices that should be applied to most electrohydraulic steering systems. Procedures that are not available in the MRC's and technical manuals are outlined.

562-10.1.2 PRECAUTIONS. Significant problems can be avoided if the following precautions are taken while performing any maintenance procedure on the system.

a. **Safety** . All safety guidelines should be followed at all times (see paragraph 562-1.3 for a summary listing).
b. **Avoiding contamination** . Whenever the hydraulic system is opened to the atmosphere, small particles in the air and any dirt or grime near the opening can enter the system. These contaminants readily travel throughout the hydraulic system and accelerate wear on the components. This contamination can be avoided by cleaning around the area of a filler cap or fitting before opening it, and by capping or covering the opening if it is to be exposed to the atmosphere for any length of time.
c. **Proper fluids, lubricants, and other components** . Most fluids and lubricants have special properties and are not always compatible with fluids or lubricants conforming to different military specifications. The MRC's identify the correct fluids, lubricants, cleaners, and equipment for performing each maintenance action. These requirements should always be followed unless it is known with certainty that a substitution can be made.

562-10.1.3 MAINTENANCE GUIDELINES. The MRC's provide preventive maintenance instructions and schedule requirements for the particular steering system. The following visual inspections should be performed on the equipment to identify any potential problems.

a. The oil level in each of the supply tanks, the head tanks, and the storage tank should be within the proper limits. The oil level in the supply tanks may fluctuate during operations that involve large rudder swings. This is considered normal as long as the fluid level returns to the proper level.
b. The temperature gages should show readings within the normal operating temperatures. Most systems operate between 60 and 135 degrees F.
c. The pressure gages (main, servo, and replenishment) should be checked to verify that the readings are not above the specified limits. These pressures vary during operation and are different for each system. Consult the technical manual for the proper pressure readings.

d. Check the system piping and components for signs of external leakage. Some oil leakage past the ram packing is allowed, but it should not exceed approximately 1/2 pint during a 24 hour period.

e. The oil filters should not have the pressure drop indicator showing that the filter element is clogged. When this occurs, the filter element should be changed immediately.

f. The linkages, control rods, and follow-up system should be intact. Components should not be bent or broken.

g. There should not be any excessive noise or vibration in the system.

h. The ram pin should be in its correct position. The fasteners on the ram pin plates should be checked to make sure they are not loose and that they are lockwired (if they are supposed to be lockwired).

i. The Rotary Hydraulic Power Unit or servo motor system that rotates the shaft leading into the differential should be checked for any external leakage.

j. The foundation fasteners should be checked to make sure that none are loose.

k. There should not be any unauthorized equipment stored in the steering gear room(s).

562-10.2 HYDRAULIC FLUID CLEANLINESS

562-10.2.1 CLEANLINESS REQUIREMENTS. The cleanliness, or lack of contamination, of the hydraulic system is extremely important in maintaining the steering system. Any extraneous material that is present in the hydraulic system can be considered a contaminant. Most steering systems are required to have a fluid cleanliness level of NAS 1638 Class 9. For particles in the 5 to 15 micron size range, the number of particles allowed can be in accordance with NAS 1638 Class 10 requirements. Newer steering systems that have electrohydraulic servo valves have more stringent cleanliness requirements, usually NAS 1638 Class 8. The water content of the hydraulic fluid in any system should not exceed 0.5 percent. The maximum acceptable neutralization number is 0.06. Fluid cleanliness can be controlled by preventing contaminants from entering the system, proper filtration, and periodic fluid sampling. **NSTM Chapter 556, Hydraulic Equipment, (Power Transmission and Control)** , provides a detailed explanation of fluid cleanliness.

562-10.2.2 SOURCES OF CONTAMINATION. The majority of fluid contamination in a system results from normal operation. When the surfaces of close-fitting components slide relative to each other, small fragments of metal are worn away. Debris such as paint, metal chips, and welding slag can be introduced into the system during installation or repair work. Small particles in the air and any dirt or grime near an opening in the hydraulic system can easily enter the system during maintenance procedures. These metal fragments and debris can be carried by the fluid throughout the system. The particles can get into the clearances of the moving parts and accelerate wear. Water from condensation in the hydraulic fluid tanks is another source of contamination. Water dilutes the hydraulic fluid and accelerates the formation of rust. Air entrained in the hydraulic fluid is a contaminant. Air can enter the system through improperly fitted suction and return line flanges, the shaft seals of the pumps, and the cylinder packings. Air in the hydraulic fluid causes changes in the system response, the positioning accuracy of the rudder actuator, increases the noise level, and can cause the pump to cavitate.

562-10.2.2.1 Hose Installation. Hoses are removed from the steering system periodically for hydrodynamic testing at a shore facility. Testing is performed in accordance with S6430-AE-TED-010, **Technical Directive for Piping Devices, Flexible Hose Assemblies** . The hoses should be cleaned and capped when they are returned to the ship, otherwise they should not be accepted. Prior to installation, the cleanliness of each hose should be checked to ensure that there is no debris within the hose assembly. The procedure is simple. Moisten a lint-free cloth with hydraulic fluid. Attach a piece of wire that is longer than the hose length to the cloth. Pull the cloth through the hose with the wire. If a black film, rubber particles, or any type of gummy substance is seen on the cloth, the hose must be flushed before it is installed. The cloth test should be repeated after the hose has been flushed, capped, and returned to the ship. The hose should only be installed if it is clean. Contaminants in the hose from the hose cutting process and from the glue used on the hose fittings can easily enter the pump and damage the pump's internal components.

562-10.3 FLUID SAMPLING

562-10.3.1 OBTAINING SAMPLES. Fluid sampling should be performed whenever fluid contamination is suspected or as required by the MRC's. Fluid samples should be taken from the main lines that connect the pump ports to the rudder actuator. The circulating fluid in these lines provides a representative sample of the fluid that is being pumped. Some steering systems have been equipped with vent and test valves in the hydraulic lines for obtaining fluid samples (see paragraph 562-4.18). Other systems require the use of pressure gauge ports.

562-10.3.1.1 Pressure Gauge Port Sampling. When pressure gage ports are used to obtain a fluid sample, the following procedure should be followed:

1. Operate the power unit until the normal operating temperature is reached. The power unit should be operating while the sample is taken.
2. Clean the area around where the sample will be taken. Dirt or dust particles that enter the fluid sample bottle will lead to inaccurate contamination readings.
3. Ensure that the sample bottle is completely clean and completely air dry. Any moisture in the bottle will be considered water contamination of the system.
4. Close the valve for the pressure gauge line, disconnect the gauge, open the valve and allow a pint or quart of fluid to drain into a bucket. Once some of the fluid has drained, fill the sample bottle.
5. Close the valve, reconnect the pressure gauge, and re-open the valve.

562-10.3.1.2 Vent and Test Valve Sampling. If vent and test valves are installed in the system, these valves can be used to collect fluid samples by attaching the portable hose assembly to the valve. Allow a pint to quart of fluid to drain into a bucket to eliminate any particles or fluid that may have settled from getting into the sample. After enough fluid has drained, fill a clean, dry sample bottle with fluid.

562-10.3.2 VISUAL INSPECTION. After obtaining the fluid sample, allow the sample to settle for at least one hour, then examine the fluid. A cloudy or milky appearance indicates fluid emulsification (oil/water/air contamination). A layer of clean water beneath the fluid or milky-appearing strings within the fluid are signs of water contamination. Granules or darkness seen at the bottom of the sample when it is held up to a light are signs of particulate contamination.

562-10.3.3 FLUID ANALYSIS. An analysis of the hydraulic fluid contamination by a naval test facility is required in accordance with PMS or whenever one of the following conditions exist:

a. Immediately before overhaul.
b. Immediately before the first sea trials following an overhaul.
c. Immediately after sea trials following an overhaul.

d. After repairs have been accomplished on the hydraulic system or on hydraulic components that required the hydraulic system to be opened.

e. When reliability is in doubt.

Whenever a fluid sample is taken, the sample should be marked with the ship's name and date, the sample point, and the approximate length of time the system was in operation before sampling.

562-10.4 REMOVING FLUID CONTAMINANTS

562-10.4.1 FILTERS AND STRAINERS. Steering systems use filters conforming to MIL-F-24402, **Filters, (Hydraulic), Filter Elements (High Efficiency), and Filter Differential Pressure Indicators, General Specification For** or MIL-F-24702, **Filter Elements, Hydraulic, Disposable, General Specification For** . The filter elements are not cleanable. They should be disposed and replaced when the mechanical indicator shows evidence of a clogged filter or when required by the MRC. If the filter clogs more than semiannually, the hydraulic system should be evaluated to determine the cause and eliminate the source of the contamination. Strainers, suction strainers, and breathers are located at the fill connections of the fluid tanks and at other locations to prevent large particles from entering the system. The strainers should be cleaned when dirt can be seen.

562-10.4.2 PORTABLE FILTRATION CARTS. When the contamination level of the fluid is higher than normal but there has not been a major failure that resulted in massive contamination of the system, the hydraulic fluid can be filtered by a portable filtration cart (also called a filter buggy or filtering rig, National Stock Number 4330-01-044-7992). Systems with sediment or particle contamination that can be detected by visual examination of the fluid sample should be filtered with the filtration cart.

1. Check that the fluid level in the supply tank is at the proper level for normal operation.
2. Connect the filtration cart to the supply tank.
   a. If the tank has quick-disconnect fittings, connect the portable filter suction hose to the lower quick-disconnect fitting. Connect the filter discharge to the upper quick-disconnect fitting.
   b. If the tank is not fitted with quick-disconnect fittings, put the suction hose as close to the bottom of the reservoir as possible. Put the filter buggy return hose in the top of the reservoir, keeping the hoses as far apart as possible.
3. Open the quick-disconnect shut-off valves if the quick-disconnects were used to connect the hoses.
4. Energize the portable filter unit and start the hydraulic pumps. Allow the fluid to circulate for one hour. Cycle the steering gear once every 5 minutes to prevent heat build-up.
5. Check that the hydraulic fluid level has not dropped below the low level mark. The fluid level will fluctuate when the steering gear is cycled.
6. Obtain a sample of hydraulic fluid for analysis.
7. Stop the filter unit and stop the hydraulic pump.
8. Check that the quick-disconnect shut-off valves are closed, if they are part of the configuration.
9. Disconnect or remove the hoses from the tank.
10. Return equipment to readiness condition.

More information on filtering rigs can be found in **NSTM Chapter 556, Hydraulic Equipment (Power Transmission and Control)** .

562-10.4.3 FLUSHING PROCEDURES. The steering gear hydraulic system seldom requires flushing. System or component flushing may be required only as a result of one or more of the following conditions:

a. Installation of a new system during ship construction or an alteration that results in the replacement of many system components.

b. Catastrophic failure of a system component that results in major contamination of the hydraulic system.

c. Major contamination of the hydraulic fluid from an external source.

d. Major system repair that involves pipe welding, brazing or drilling operations.

562-10.4.3.1 Installation or Major Alteration. The hydraulic system, as well as the remaining steering gear components, are installed during the ship construction. The shipbuilder assumes responsibility for hydraulic system cleanliness and any appropriate system or component flushing necessary. The responsible shipyard may use its own NAVSEA-approved flushing procedures or may use those procedures provided in MIL-STD-419, **Cleaning, Protecting, and Testing Piping, Tubing, and Fittings for Hydraulic Power Transmission Equipment** . Major system alterations, especially those calling for piping rip-out and the installation of new piping runs, may require flushing those portions of the piping system affected. In most cases, total system flushing should not be necessary. Pipe segments and piping adapters should be flushed individually in a qualified shore facility. The clean components should then be capped in accordance with MIL-STD-419 and transported to the ship for installation. New pumps, valves, rams and other assembled hydraulic components may not require flushing if proper cleanliness standards, verification methods and transportation requirements have been specified during the procurement of the components. After completing installation of the system aboard ship, hydraulic fluid sampling should be performed. If extreme contamination is not present, hydraulic system filters may be used to filter the hydraulic fluid by circulating the fluid through the piping using the system pumps and valves. Repeated sampling may be necessary until the hydraulic fluid meets the fluid cleanliness requirements specified for the particular steering system. (Cleanliness requirements vary with the component manufacturer’s specifications for the equipment. The equipment requiring the lowest particle count limits determines the overall system cleanliness.) When flushing is completed, the filter elements should be replaced to ensure full capacity.

562-10.4.3.2 Catastrophic Failure of System Components. A component catastrophic failure most likely will result within rotating hydraulic equipment, such as pumps. High fluid temperature, improper hydraulic fluid, excessive water in the hydraulic fluid and externally-introduced contamination, may all contribute to an extremely high wear rate, causing a considerable volume of large metallic particles to be generated and released into the system. A failure such as this requires careful examination of the entire steering gear hydraulic system to determine the extent of the damage; not only to the primary component of failure, but also to ancillary components. After repairing and replacing the failed component(s) as well as isolating and correcting the cause of failure, system flushing should be performed. If possible, system components should be removed from the ship and cleaned and flushed within an approved shipyard facility. If a suitable facility is not available, the steering gear hydraulic system may be flushed in accordance with **NSTM Chapter 556, Hydraulic Equipment (Power Transmission and Control)** and as detailed in MIL-STD-419. The steering gear hydraulic system is not a looped circuit. The hydraulic ram or the rotary actuator presents a barrier to the fluid. Thus, the fluid leaving the pump and the fluid returning are different. Therefore, flushing the steering gear hydraulic system can be performed only through sections of the piping at any one time. For best flushing results, the individual piping sections may be isolated in accordance with their service duty. The recommended piping sections are:

a. High-pressure

b. Suction and return-line

c. Control and emergency pump

d. Gauge.

Figure 562-10-1, Figure 562-10-2, Figure 562-10-3, and Figure 562-10-4 portray a recommended sectionalizing of a typical steering gear hydraulic system. Although the diagrams are based on the CG 47 Class steering system, the general service sections identified are common to other ship classes. The differences will be found in the sizes of the components, the piping and compartment arrangements, and the porting locations of the major components. Individual ship steering system technical manuals should be consulted to determine the location of an equivalent section of piping on the ship class where work is being performed.

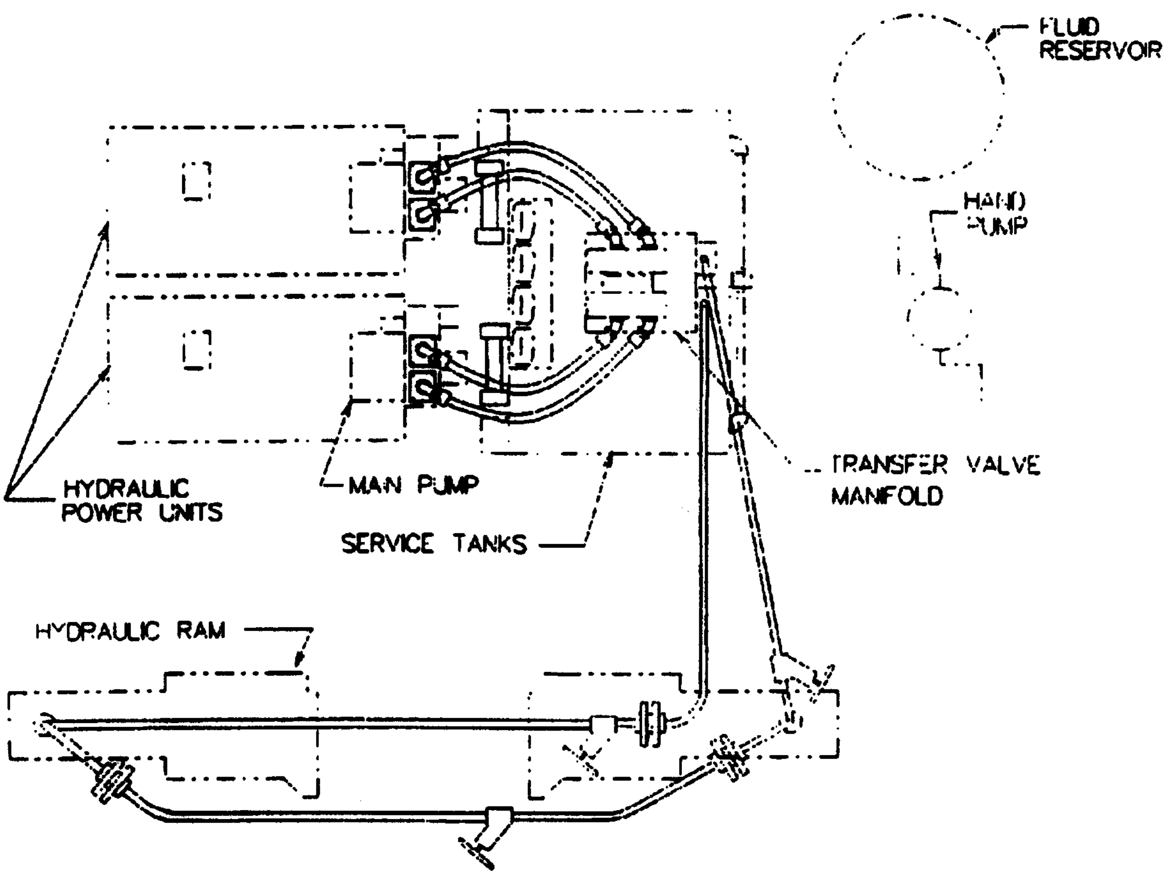


Figure 562-10-1. High-Pressure Piping

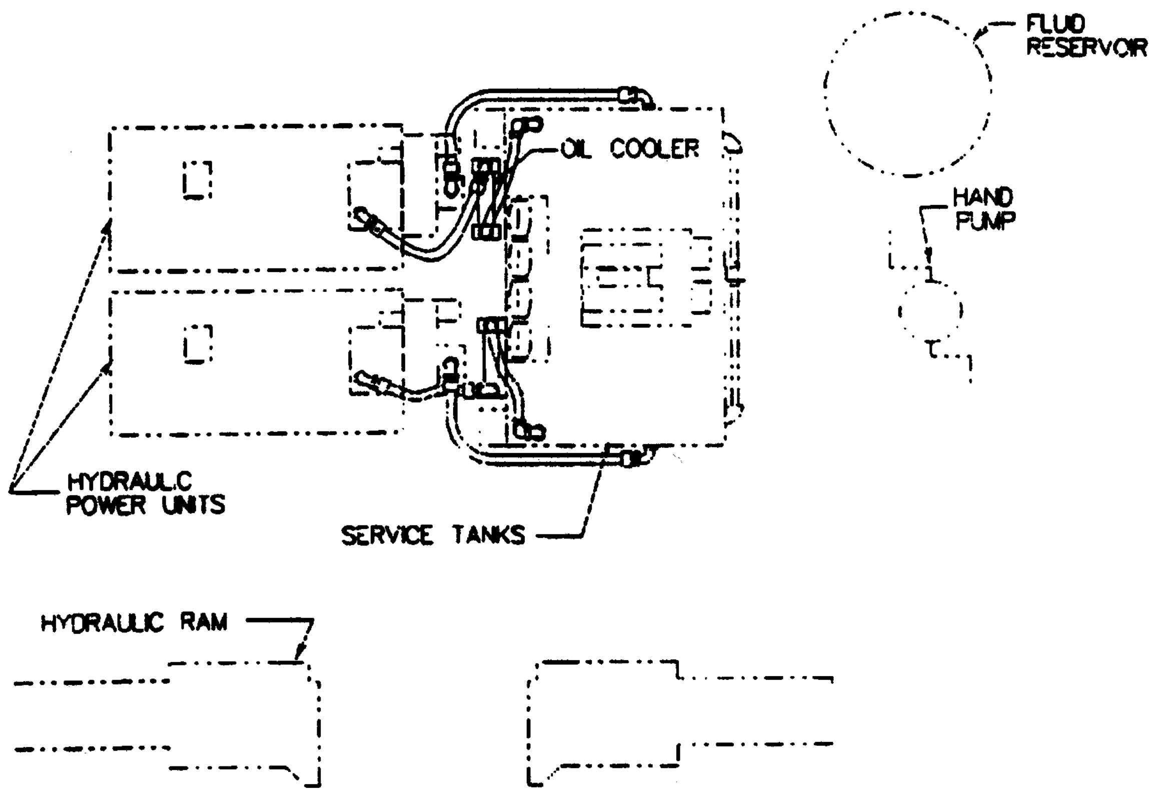


Figure 562-10-2. Suction and Return-Line Piping

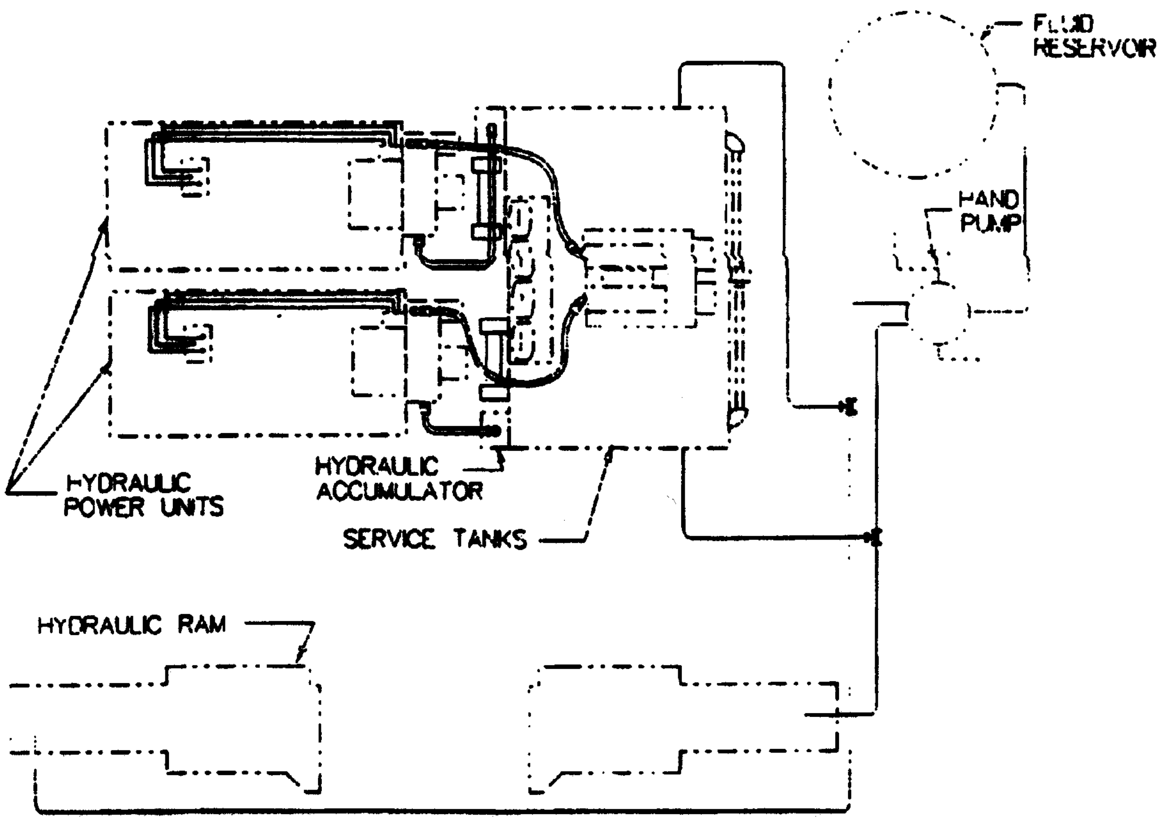


Figure 562-10-3. Control and Emergency Pump Piping

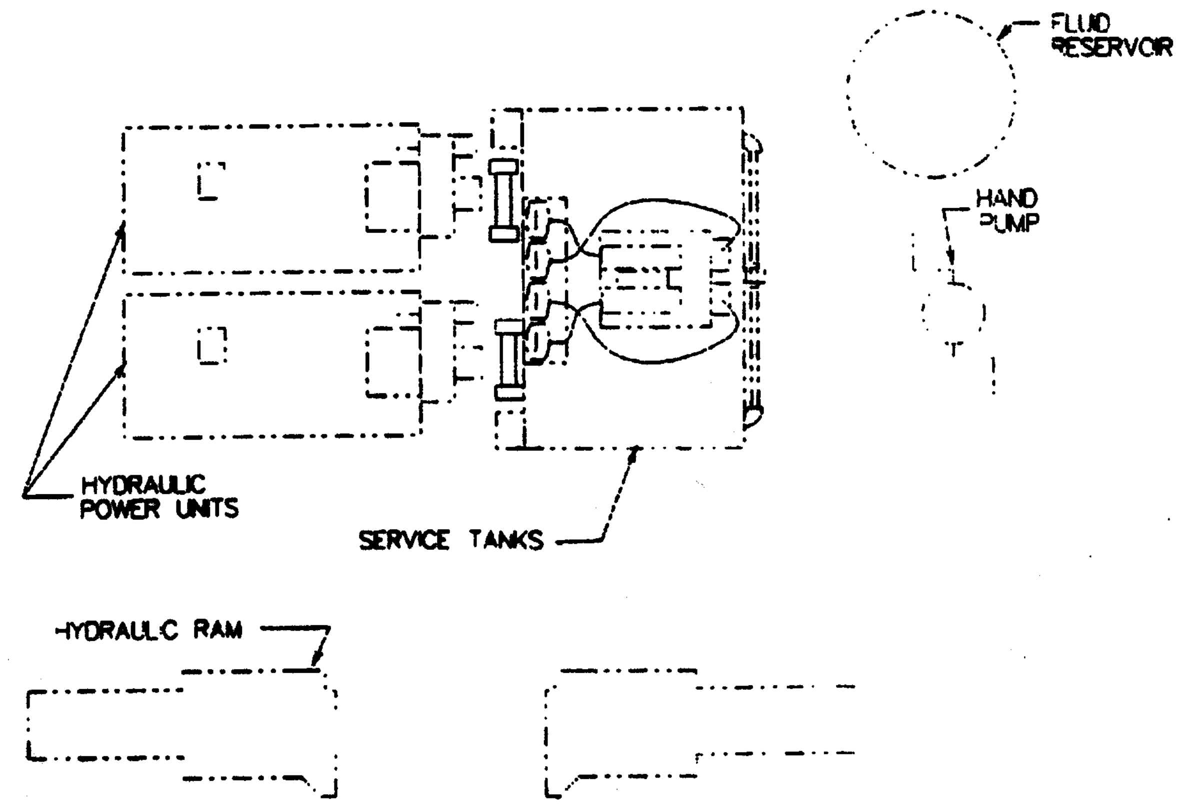


Figure 562-10-4. Gauge Piping

562-10.4.3.2.1 High-pressure Piping. As stated, the components flushing should be performed in a qualified shore facility, if possible. If this method is not available, flushing may be performed in accordance with MIL-STD-419. Piping should be disconnected at the pump and at the distribution or transfer valves. The connecting piping may now be flushed using an external flushing pump and jumper hoses connected to establish a loop. In a similar manner, piping between the transfer valve manifold and the hydraulic rams or rotary actuators should be disconnected and short-circuited to establish a flushing loop. Valves and pumps should be cleaned in the ship's hydraulic shop through disassembly, careful cleaning and reassembly. Individual component maintenance procedure information, found in the relevant technical manual, should be observed. Single-acting hydraulic rams may be flushed through draining and refilling with clean hydraulic fluid. When equipped with double-acting cylinders or rotary actuators, the actuators may need full disassembly and internal cleaning to remove the contamination. After full reassembly of the system, further sampling and fluid filtration should be performed.

562-10.4.3.2.2 Suction and Return-line Piping. Hydraulic system sump tanks should be drained and cleaned prior to any flushing of the attached piping. Suction strainers within the sumps should be cleaned prior to refilling the sumps with fluid. Suction and return-line piping should be disconnected from the sump tank and the system pump and then looped with a jumper hose similarly to the high-pressure piping described above. Components such as heat exchangers and shut-off valves may be left in the loop and flushed at the same time. Flushing this loop in the reverse flow direction may be helpful in inducing more particles to dislodge from cavities within the components. However, if a suction filter is present, the internal filter element should be removed to prevent the element from collapsing. A new element should be installed when the flushing is complete.

562-10.4.3.2.3 Control and Emergency Pump Piping. Control piping may be the most difficult to flush since few looped circuits usually exist and most of the piping or hose runs are dead-ended. All valve pilot lines and control signal lines should be disconnected at both ends and should be flushed individually. Emergency pump piping should be flushed similarly to the high-pressure and suction and return-line piping previously described.

562-10.4.3.2.4 Gauge Piping. Since all of the gauge piping is dead-ended and fluid in these lines is essentially static, flushing these lines may be unnecessary. If the presence of contamination is suspected, the gauge lines may be flushed individually similarly to the control piping described above.

562-10.4.3.3 External Source Contamination. The results of contamination introduced from an external source may be similar to those of a catastrophic component failure. Indeed, a catastrophic component failure may result from such a contamination. System flushing, therefore, should be performed similarly to the procedures described in the previous section. Depending on the type of the contamination, all of the system hydraulic fluid should be drained and filtered using an external filtration system. A chemical contamination that results in degradation or break-down of the fluid requires discarding and replacing the fluid. Disposal of the contaminated fluid shall be in accordance with local, state and federal laws or the fluid shall be retained in containers for shore disposal.

562-10.4.3.4 Pipe Welding, Brazing or Mechanical Repair. The pipe section designated for welding, brazing, drilling or any other repair procedure shall be disconnected from the remainder of the system prior to any work being performed. When the repair or modification has been completed, the piping section should be cleaned and hydrostatically tested using the procedures for cleaning and pickling detailed in MIL-STD-419.

562-10.5 LUBRICATION

562-10.5.1 STEERING GEAR. All moving components of the steering gear require lubrication. Each steering system has a lubrication chart posted in the steering gear room that identifies where the equipment must be greased. The chart can also be found in the system technical manual. Grease fittings are provided at several locations in the system so that disassembly of the equipment is usually not needed. VV-G-632, **Grease, Industrial, General Purpose** , is the proper grease for the sliding blocks and should be applied through the grease fittings.

562-10.5.2 RUDDER BEARINGS. Proper lubrication of the rudder bearings is important to system operation. While a few ship classes have oil filled bearing, most rudder bearings must be greased. When greasing the bearings, the plug should be removed from the vent line and grease should be pumped in from the other side of the bearing until fresh grease comes out of the vent line. The rudder should be cycled from full port and full starboard positions while lubricating the bearing. MIL-G-24139,**Grease, Multipurpose, Water Resistant** is the type of grease preferred for use on rudder post bearings that may come into contact with seawater. **NSTM Chapter 243, Propulsion Shafting** provides more information on rudder bearing maintenance.

562-10.6 RELIEF VALVE TESTS

562-10.6.1 DESCRIPTION. The procedure for testing the main relief valves of the steering gear depends on the configuration of the cylinder shut-off valves. The pressure settings of the relief valves vary among the different ship classes and are usually identified in the PMS with acceptable tolerances. If tolerances are not specifically identified, the values in Table 562-10-1 can be used for guidance. The relief valve settings and the procedures for performing relief valve tests are outlined in the MRC's. If the main pumps are equipped with pressure compensators, the pressure compensators will interfere with the relief valve test (see paragraph 562-4.4.3.3). During relief valve testing, the setting of the pressure compensator should be raised temporarily. When relief valve testing is completed, the pressure compensator should be reset. Some ship classes, such as the DD 963 or FFG 7 classes, can test the relief valves by shutting off certain cylinder valves to block the fluid flow. Other ships rely on the use of test stops. This procedure involves moving the rudder to either the right or left until the tiller crosshead contacts the test stops. The stops are installed only for the test and are removed afterward. The stops prematurely stop rudder travel and cause the hydraulic system to increase pressure in an attempt to overcome them. When the pressure in the cylinder reaches the relief valve setting, the relief valve lifts. The test stops essentially protect the copper and steel stops on the cylinders or tie rods. When the test stops are needed for the test, they must be manufactured by the ship's force. The following paragraphs provide guidance for manufacturing the test stops and determining the type, size and number of stops needed. The correct procedure for installing test stops on most steering gears is described. Once the stops are made, they should be marked and stored on brackets in after steering. The stops can be reused for future relief valve tests.

Table 562-10-1 TOLERANCES FOR RELIEF VALVE SETTING

Relief Valve Setting (lb/in^2)	Acceptable Tolerance (lb/in^2)
≥1500	±50
350 to 1500	±25
<350	±20

562-10.6.2 TEST SET-UP. There are three steps involved in determining the correct type, number, and size of test stops for a steering gear.

1. Locate and identify all steel stops and copper crushing pieces. There are two general types of installations for steel stops and crushing pieces: a tie rod mount and a cylinder mount (Figure 562-10-5). Tie rod mounts generally have one crushing piece and one steel stop at each end of the tie rod. Double tie rod installations will have a total of four copper stops and four steel stops. If the stops and crushing pieces are installed on the cylinder faces, there will always be two on each cylinder. When looking at the cylinder face, one assembly will be at the 7 o'clock position and the other at the 5 o'clock position. It is important that all stops be located before performing the test. This is especially important when two rams are used to operate a single rudder stock (Figure 562-10-6). The number of test stops required will equal the total number of steel stops installed on the equipment. Equipment damage can occur if test stops are not installed in place of, or over, all crushing pieces.

2. Determine the type of test stops and the correct installation procedure. There are three general types of test stops: the U-block, split sleeve, and cap. The type of test stop that is best suited for the particular gear depends on the type of steel stop that is installed on the equipment. Figure 562-10-7 shows the three basic types of stop assemblies installed on most Navy steering gears and identifies the type of test stop that should be used. The type of test stop manufactured and used for the relief valve test should correspond to the type of stop shown in the figure.

   a. **U-block.** The U-block should be used with the tie rod mounted stop assembly shown in Figure 562-10-7a. Notice that the steel stop has a smaller diameter facing the crosshead so that a split-sleeve copper stop can be installed over a portion of the steel stop. The split sleeve type crushing piece is held in place by bands or clamps. During the test, the copper stop piece is removed and replaced with the U-block. The U-block is draped over the tie rod, flush against the face of the steel stop.

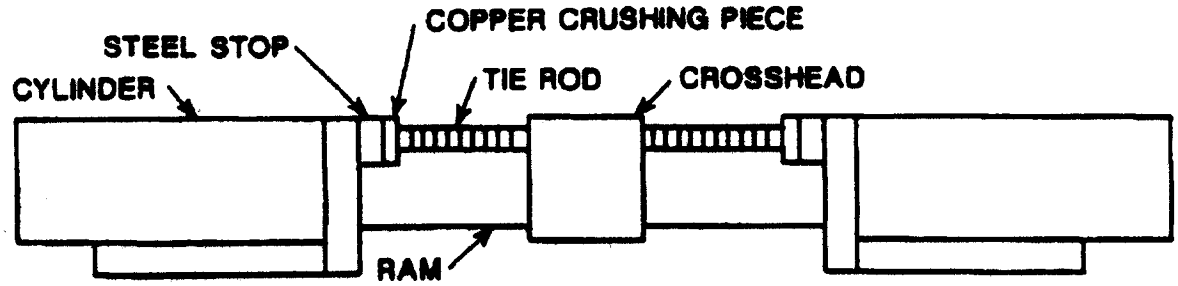
   b. **Split sleeve.** The split sleeve test stop should be used with the tie rod mounted stop assembly shown in Figure 562-10-7b. The steel stop has a larger diameter near the crosshead since it is essentially a flange. A split sleeve type crushing piece fits within this portion of the steel stop. Set screws running through the steel stop hold the crushing piece on the tie rod. For the test, the split sleeve copper stop is removed and replaced with a split sleeve test stop. The test stop rests flush against the inner face of the steel stop.

   c. **Cap.** The cap-type test stop should be used for all cylinder mounted stop assemblies. Cylinder mounted stop assemblies consist of a copper crushing piece that fits within a cylindrical steel stop as shown in Figure

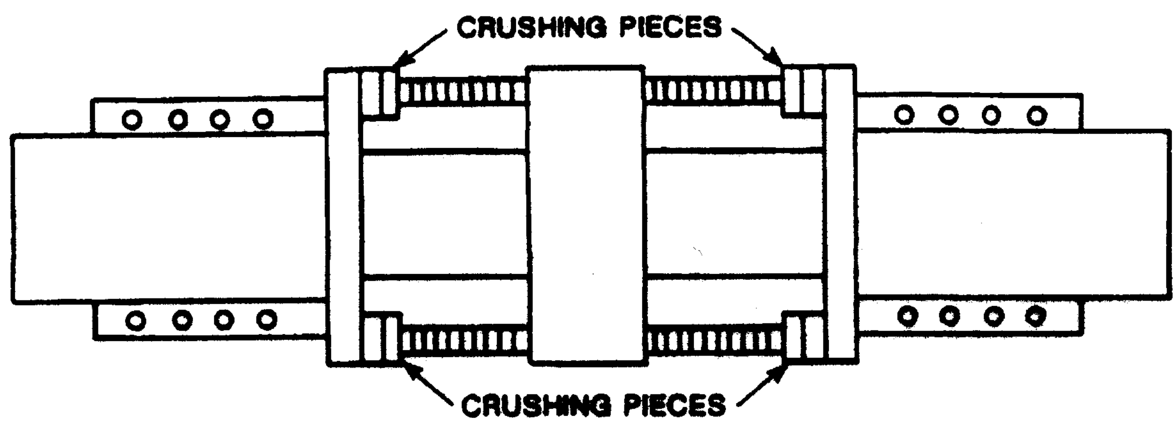
562-10-7c. The crushing piece is longer so that the crosshead will contact the copper piece before it hits the steel stops. The cap-type test stop slides over the copper stop and rests against the end of the steel stop. The copper stop does not have to be removed. Two set screws should be used to secure the test stop to the copper crushing piece.

3. Determine the size of the test stops.
   a. **U-blocks.** To determine the size of the U-block style test stop, refer to Figure 562-10-8 and proceed as follows:
      (1) Remove the copper crushing pieces.
      (2) Put the rudder 3 degrees from the hard-over position. Measure the distance (L) between the shoulder of the steel stop and the crosshead. This will be the length of the U-block.
      (3) The minimum material thickness (T) of the U-block should be equal to the height T of the steel stop shoulder above the tie rod.
      (4) The radius (R) of the U-bend should be 1/2 of the tie rod diameter (D) plus 1/32 inch.
      (5) The height (H) of the U-block should be at least two times the diameter (D) of the tie rod.
      (6) The material used to manufacture the test stop should be a low carbon alloy steel (mild steel).
   b. **Split-sleeve.** To determine the size of a split sleeve, refer to Figure 562-10-9 and proceed as follows:
      (1) Remove the copper crushing pieces.
      (2) Put the rudder 3 degrees from the hard-over position. Measure the distance (L) between the inner face of the steel stop and the crosshead. This will be the length (L) of the test stop.
      (3) The split sleeve inside diameter (ID) should be 1/32 inch larger than the diameter (D) of the tie rod.
      (4) The split sleeve outside diameter (OD) should be 1/32 inch less than the ID of the steel stop extended flange. The sleeve OD should equal [D + 2T - (1/32)] inch.
      (5) After machining, split the sleeve into two equal parts along its length. Weld two clamping tabs on each half and drill them for 1/2 inch diameter bolts.
      (6) The material used to manufacture the test stop should be a low carbon alloy steel (mild steel).
   c. **Cap-style test stop.** To determine the size of a cap style test stop, refer to Figure 562-10-10 and proceed as follows:
      (1) Put the rudder 3 degrees from the hard-over position. Measure the distance (L) between the end of the steel stop and the crosshead. This will be the length (L) of the cap.
      (2) The outside diameter (OD) of the cap should equal the outside diameter (D) of the steel cap plus 1/32 inch.
      (3) The inside diameter (ID) of the cap should equal the diameter (C) of the copper crushing piece plus 1/32 inch.
      (4) The depth (A) of the cap bore should be 1/2 inch deeper than the projection (B) of the copper crushing piece.
      (5) After machining, drill and tap two holes, 90 degrees apart, for 3/8-16 NC set screws. The centerline (S) for the set screws should be 1/2 of the (B) dimension.
      (6) The material used to manufacture the test stop should be a low carbon alloy steel (mild steel).

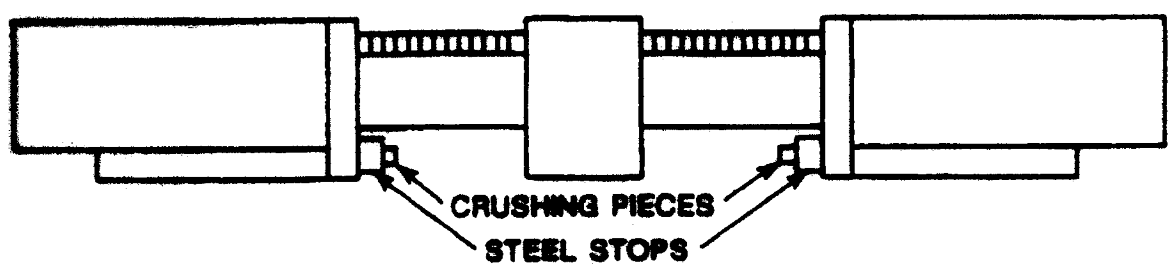
Before conducting the steering gear relief valve tests, always check that all the crushing pieces have been located on the side of the cylinder or tie rod where the crosshead will be turned. Check that their associated steel stops have been protected with a test stop. Secure the split sleeve and cap style test stops to the equipment by mechanical means. Never allow personnel to hold them in place. During the test, turn the trick wheel slowly to permit the hydraulic system to build up pressure slowly. Only one pump should be operating. Do not operate at the relief valve setting for more than three seconds. Never attempt to test the relief valves by locking the rudder with the tie rod jacking nuts. This will damage the equipment.



a. SIDE VIEW OF SINGLE RAM ASSEMBLY WITH TIE ROD MOUNTED COPPER CRUSHING PIECES.



b. TOP VIEW OF SINGLE RAM ASSEMBLY WITH TIE ROD MOUNTED COPPER CRUSHING PIECES.



c. SIDE VIEW OF SINGLE RAM ASSEMBLY WITH CYLINDER MOUNTED COPPER CRUSHING PIECES.

Figure 562-10-5. Installations for Steel Stops and Crushing Pieces

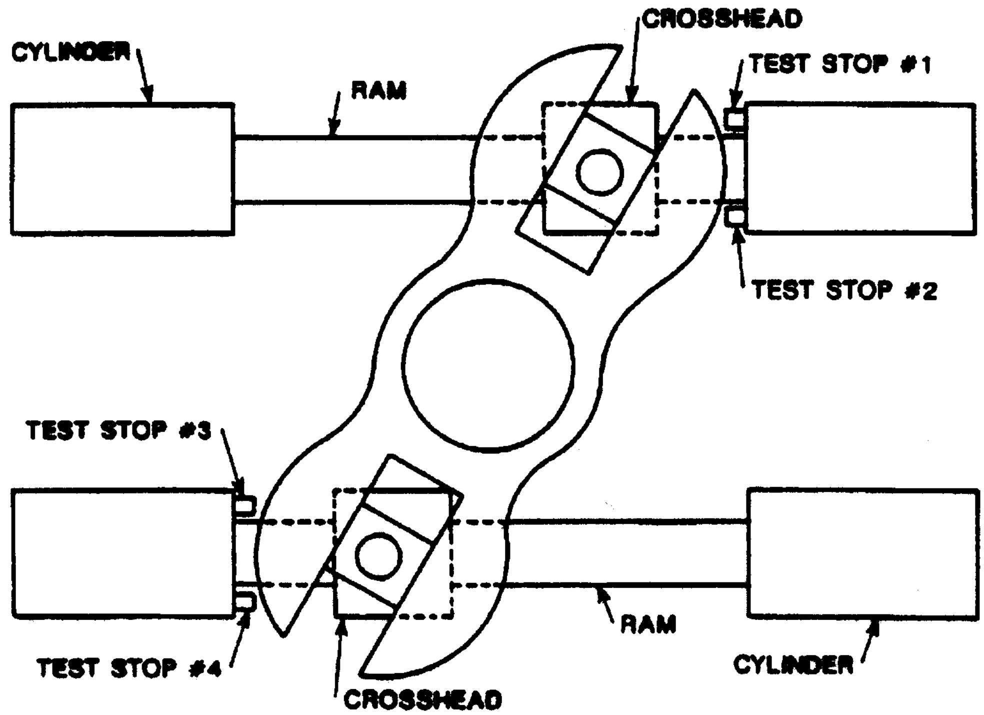
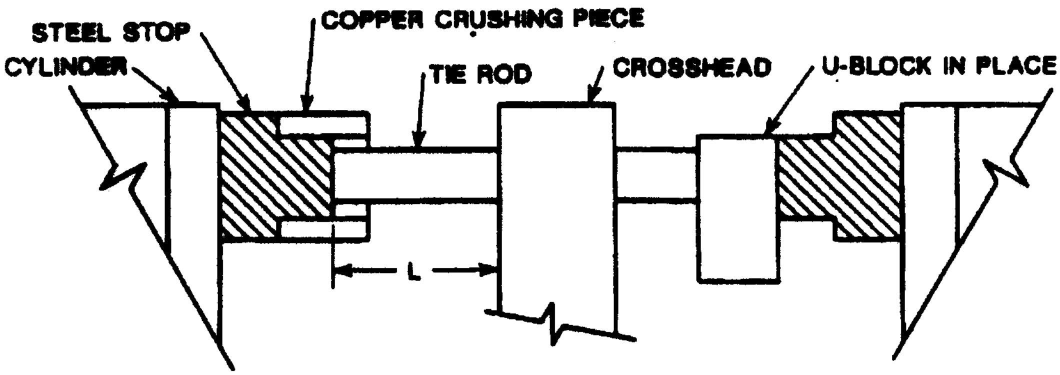
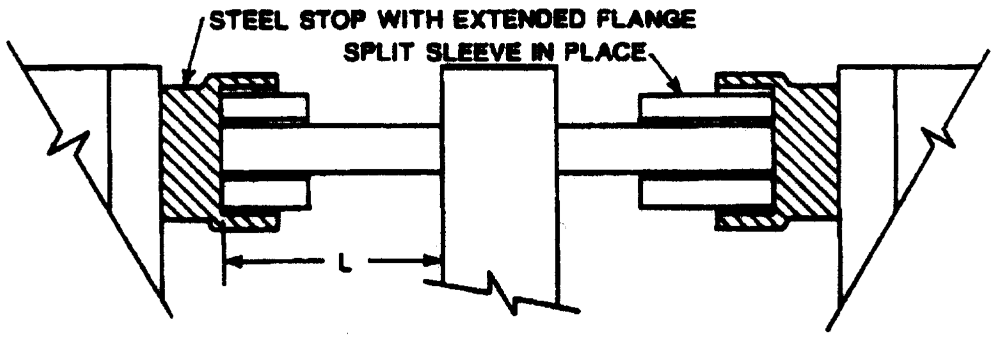


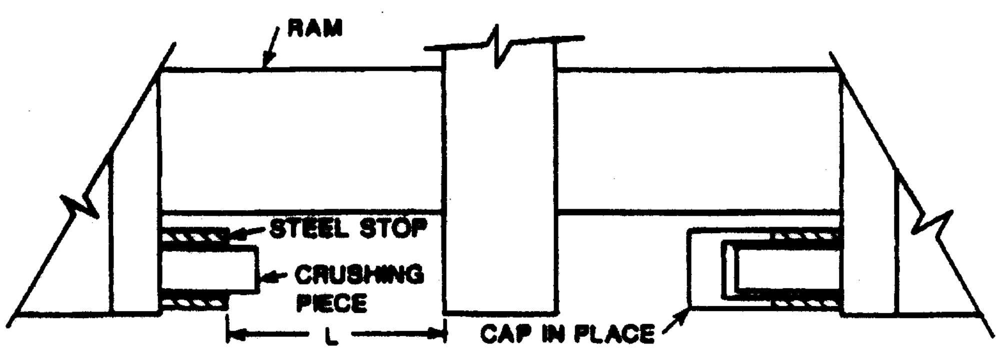
Figure 562-10-6. Double Ram Rapson-Slide with Cylinder-Mounted Stops



a. CUT-A-WAY VIEW OF TIE ROD MOUNTED STEEL STOPS WITH RIGHT CRUSHING PIECE REMOVED AND U-BLOCK INSTALLED.



b. CUT-A-WAY VIEW OF TIE ROD MOUNTED STEEL STOP WITH RIGHT CRUSHING PIECE REMOVED AND SPLIT SLEEVE INSTALLED.



c. CYLINDER MOUNTED STEEL STOPS. STEEL TEST CAP INSTALLED OVER RIGHT CRUSHING PIECE.

Figure 562-10-7. Typical Stop Assemblies

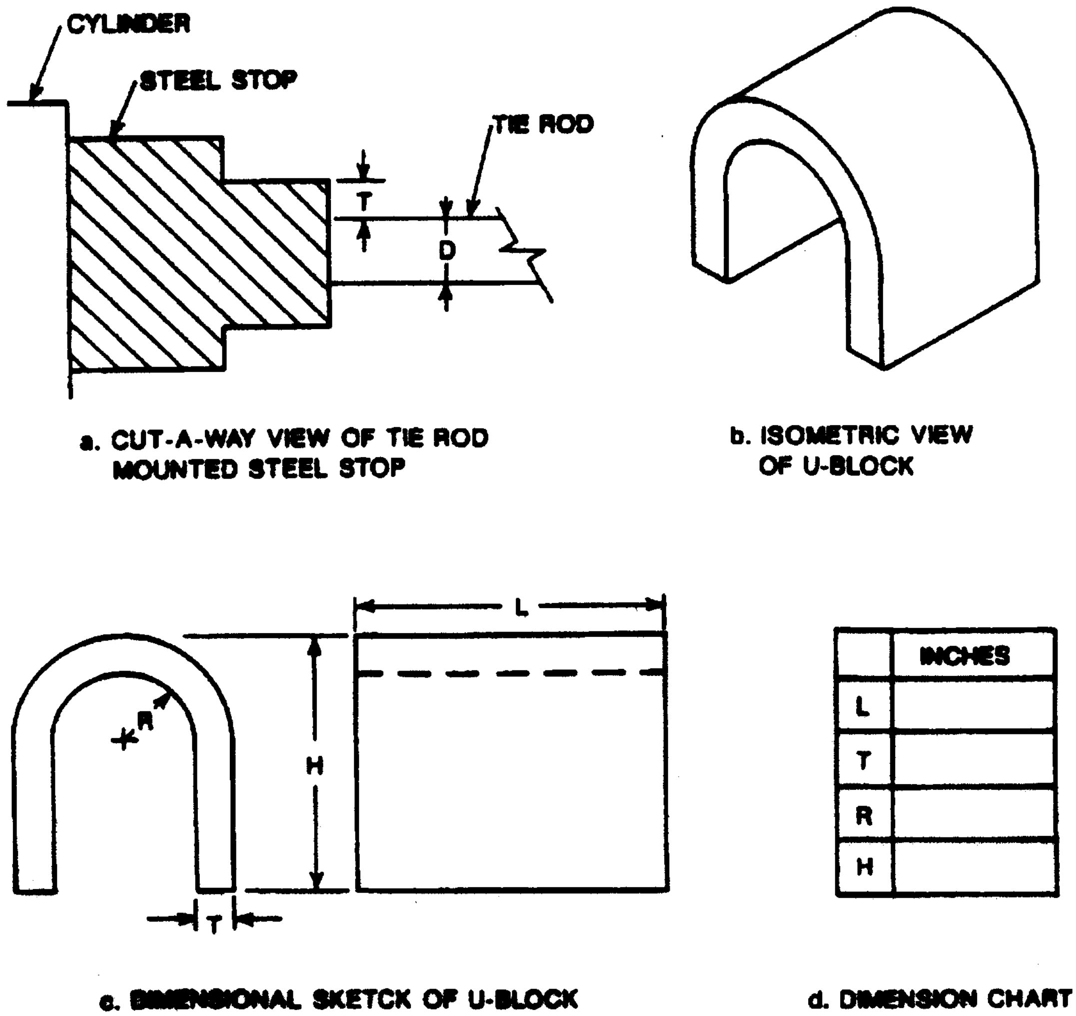
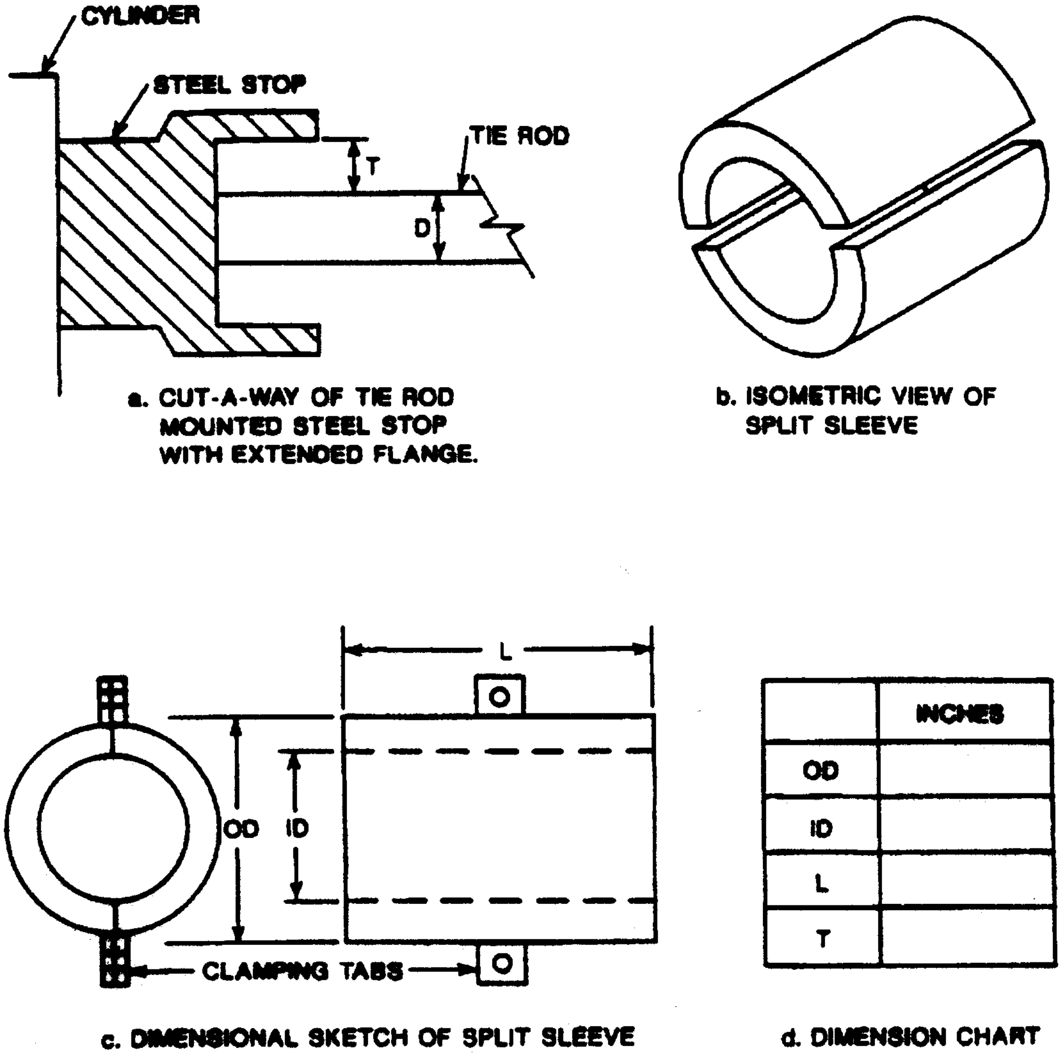


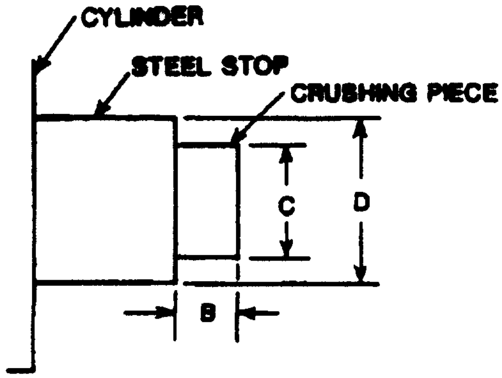
Figure 562-10-8. U-Block Style Test Stop



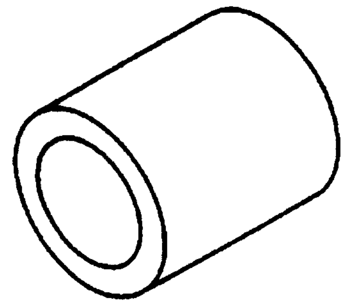
	INCHES
OD	
ID	
L	
T	

d. DIMENSION CHART

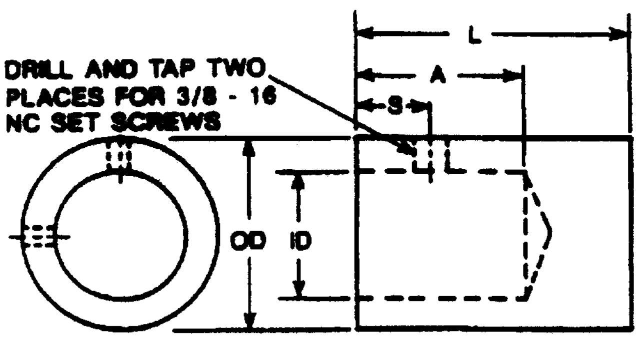
Figure 562-10-9. Split Sleeve Style Test Stop



a. SIDE VIEW OF CYLINDER MOUNTED CRUSHING PIECE



b. ISOMETRIC VIEW OF STEEL CAP



c. DIMENSIONAL SKETCH OF CAP

	INCHES
OD	
ID	
L	
A	
S	
B	
C	
D	

d. DIMENSION CHART

Figure 562-10-10. Cap Style Test Stop

562-10.7 PUMP TESTS

562-10.7.1 GENERAL. Pump tests are performed to determine whether the pump is operating properly and the pump settings or adjustments are correct. Pump test procedures are outlined in the MRC's and vary depending on the type of pump being tested. Equipment manuals for the pumps describe in detail the porting, rotation, output, and other features that affect operation. These manuals should be used as references if needed when conducting pump tests. Safety precautions should always be followed. The fluid level in the pump case should be checked to ensure it is full after any maintenance is performed on the system which requires the system to be opened.

562-10.8 RUDDER RATE TESTS

562-10.8.1 DESCRIPTION. To determine the rudder rate, a hard-over to hard-over command is given while the ship is moving ahead at the maximum rated ship speed. Timing begins when rudder motion begins and ends when the rudder reaches 30 degrees (or 5 degrees before hard-over) on the other side of center. The final 5 degrees of rudder swing are not used in determining rudder rate because the steering system slows the rudder as it approaches the command angle. When rudder rates are tested pierside, the steering system is not under full power conditions. Consequently, the measured rudder rates are approximately 5 to 10 percent faster than when tested underway.

562-10.9 SIMULATED POWER FAILURE TEST

562-10.9.1 DOCKSIDE TEST. The procedure for the dockside simulated power failure/blocking valve test is as follows:

1. Secure power to idle power unit.
2. Turn helm rapidly from amidships to right 35 degrees.
3. When rudder reaches right 25 degrees, secure power to active power unit.
4. Observe rudder stopping distance. The total distance should not exceed 3 degrees.
5. Ensure that mechanical helm order and rudder position pointers on the differential dial face are matched, then restart power unit.
6 .Return rudder to amidships and repeat test steps 1 through 5 of the dockside test for the remaining power units.
7. Resume testing in this configuration when the ship is underway.

562-10.9.2 UNDERWAY TEST. The power failure test should be conducted with the ship at the maximum ahead speed or at the maximum astern speed. The maximum astern speed is limited on some ships so that the design rudder torque is not exceeded. The procedure for the underway simulated power failure/blocking valve test is as follows:

1. Beginning with rudder amidships, turn rudder to right 25 degrees.
2. After rudder has achieved the ordered angle, verify the hydraulic pump is at zero stroke and secure power to the unit for 15-20 seconds.
3. Observe rudder position with power secured and determine if there is any drift. The calculated maximum rate should not exceed 3 degrees per minute.
4. Ensure that mechanical helm order and rudder position pointers on the differential dial face are matched, then restart power unit.
5. Turn rudder to left 25 degrees and repeat steps 1 through 4 of the underway test.
6. Return rudder to amidships.
7. Repeat steps 1 through 6 of the underway test for each remaining power unit.

562-10.10 REPORTING FAILURES

562-10.10.1 CASUALTY REPORTS. Steering casualties should be reported using the lowest level Allowance Parts List (APL) number of the part that actually failed, rather than the overall APL number of the steering gear. If possible, the National Stock Number (NSN) of the failed part should also be reported.

562-10.10.2 FAILURE LOG SHEET. In the event of a failure, the operating conditions at the time of the failure should be recorded. This information can assist the technical teams in the troubleshooting and repair of the failed components. An example of the type of information that should be recorded is shown in Figure 562-10-11.

STEERING SYSTEM FAILURE LOG SHEET

Ship | Date

Description of failure.

Has the failure occurred before? Yes ☐ No ☐ When?

Noted operating or behavior problems just before failure.

At the time of the failure:

Ship Operating Conditions Normal ☐ Inport ☐ Unrep ☐ Other ____________

Station Controlling the Gear

Bridge ☐ Aft ☐ Other ____________

Steering Mode

Hand (Electric) ☐ Autopilot ☐ Nonfollow-up ☐ Differential Trick Wheel ☐

Normal ☐ Automatic ☐ Backup Manual ☐

Rudder Angle ________ degrees | Rudder Moving Yes ☐ No ☐

Command Angle ________ degrees | Which Direction?

Power Units Operating Online 1A ☐ 1B ☐ 2A ☐ 2B ☐

Power Units Operating in Standby 1A ☐ 1B ☐ 2A ☐ 2B ☐

Pump(s) on Stroke Yes ☐ No ☐

Hydraulic Pressures of the Affected HPU

Main ____________ psi

Servo ____________ psi

Replenishment ________ psi

Oil Temp ______ °F

Hot Spots in Piping or Major Component Yes ☐ No ☐

Location:

Have there been any rudder positioning problems recently such as overtravel or overshoot?

Yes ☐ No ☐ If yes, describe.

Have there been any recent maintenance activities? Yes ☐ No ☐ If yes, name them.

When was the last fluid analysis performed? What were the results?

Has there been any excessive or unusual noise or vibration from any of the power units?

Yes ☐ No ☐ If yes, which one? 1A ☐ 1B ☐ 2A ☐ 2B ☐

Figure 562-10-11. Steering System Failure Log Sheet

562-10.11 OVERHAUL

562-10.11.1 GENERAL. When the ship is in an overhaul period or a similar industrial activity environment where the steering system will not be in operation for a week or longer because the ship is dry-docked, the steering system must be protected from potential damage. Dirt and moisture are the two biggest enemies.

562-10.11.2 MACHINERY PROTECTION. Components, especially the rams, which are not painted may become pitted or show signs of corrosion if not protected. To protect the steering gear assembly, apply a medium coat of MIL-G-23549,**Grease, General Purpose** to the ram surface. Drape the ram, tie rod, ram pin assembly, follow-up linkages, and main power units with a canvas cover. If additional guards or shields are needed, metal or wooden materials plus canvas can be used for the topping cover.

562-10.11.3 ELECTRICAL EQUIPMENT PROTECTION. The following steps should be taken to protect the electrical equipment during an overhaul period.

1. Follow all safety precautions.
2. Install a drying agent and protective covering.
   a. Open the access door or remove the panel cover.

WARNING

Consider all electrical leads to be energized until positively proven they are deenergized.

   b. Test the unit with a multimeter to ensure circuits are deenergized.

WARNING

High-voltage, high capacitance components may contain voltages dangerous to life.

   c. Discharge high-voltage, high-capacitance components to electrical ground, if applicable.
   d. Install fishpaper such as MIL-I-695,**Insulation, Electrical, Paper (Slot-cell)** between accessible contact surfaces.
   e. Install silica-gel packets conforming to MIL-D-3716, **Desiccants, Activated for Dynamic Dehumidification** in the controller case at a rate of 1/2-pound for each cubic foot of space. Count the number of packets installed and note this number on a tag. Attach the tag inside of the case.
   f. Close the access door or reinstall the panel cover.
   g. Install plastic or herculite covering, if required. Seal the openings with pressure-sensitive tape.
3. If the ship is waterborne, the steering gear should be operated at least once a month by personnel who are familiar with steering gear operating procedures.
   a. Remove the canvas covering from the ram assembly.
   b. Clean the grease from the ram surface.

WARNING

Exercise extreme caution in the vicinity of the operating equipment.

c. Start one of the power units in accordance with operating procedures.
d. Engage the trick wheel for that unit.
e. Move the rudder to 30 degrees port, then to 30 degrees starboard, and return to midship position.
f. Disengage trick wheel. Stop the power unit.
g. Apply a medium coat of grease to the ram.
h. Reinstall the canvas cover.
i. Repeat the procedure so that each ram is operated.

4. If the ship is waterborne and no electrical power is available to operate the power units, the steering gear should still be operated on a monthly basis by using the hand pump.
   a. Remove the canvas covering from the ram assembly.
   b. Clean the grease from the ram surface.

WARNING

Exercise extreme caution in the vicinity of the operating equipment.

c. Line up the hydraulic system in accordance with the standard operating procedures for emergency hand steering.
d. Operate the hand pump in accordance with the standard operating procedures and move the rudder to port 5 degrees, then to starboard 5 degrees. Return the rudder to midship position.
e. Return the hydraulic system to readiness condition.
f. Remove the coupling cover from the main power unit.
g. Rotate the pump shaft several revolution by hand.
h. Reinstall the main pump coupling cover.
i. Repeat for the adjacent power unit.
j. Apply a medium coat of grease to the ram surface.
k. Reinstall the canvas cover.
l. Repeat the procedure so that each ram is operated.

5. Measure the insulation resistance for motors that have not been operated in the past 90 days.

NOTE

Existing wiring configurations of indicating lamps, or electrical interlocks on some controllers, provide a low voltage feedback circuit at auxiliary contacts when the power sources are deenergized. Be sure to deenergize the power supplies to the motor controller and tag OUT OF SERVICE. Remove the tape and covering from the controller, if required.

a. Open the motor controller access cover.

WARNING

Consider all electrical leads to be energized until it is positively proven that they are deenergized.

b. Test with a multimeter to ensure that the circuits are deenergized.

c. Measure the insulation resistance between the ship hull and the power leads on the motor. The minimum insulation resistance is 0.5 megohms for AC motors.

d. Close the motor controller access cover and reseal it if necessary.

e. Remove the safety tag and energize the power supplies.

6. Once the overhaul period has ended, the system must be prepared for use.
   a. Remove the cover from the ram and steering gear assemblies.
   b. Clean the grease from the ram surface.
   c. Remove the protective covering and drying agents from the electrical components.
   d. Open the access doors or remove the access panels.
   e. Remove the note tag and the silica-gel packets. Be sure to check that the number of packets removed is not less than the number recorded on the tag.
   f. Remove the fishpaper from the contacts if it was installed.
   g. Close the access door or reinstall the access cover.
   h. Remove the safety tag from the circuit.

REAR SECTION

NOTE

TECHNICAL MANUAL DEFICIENCY/EVALUATION EVALUATION REPORT (TMDER) Forms can be found at the bottom of the CD list of books. Click on the TMDER form to display the form.